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The Effects of the Macroeconomy on the Yield Curve in the Short and Medium Term and on the Relative Attractiveness of the Main Asset Classes

Three Empirical Essays

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Hiermit erkläre ich, Alexander Schulan, geb. am 08.08.1978 in München, an Eides statt, dass ich die vorliegende Dissertation mit dem Titel "The Effects of the Macroeconomy on the Yield Curve in the Short and Medium Term and on the Relative Attractiveness of the Main Asset Classes" selbständig verfasst und keine anderen als die angegebenen Hilfsmittel benutzt habe. Die Dissertation ist bisher keiner anderen Fakultät vorgelegt worden. Ich erkläre ferner, dass ich bisher kein Promotionsverfahren erfolglos beendet habe und dass eine Aberkennung eines bereits erworbenen Doktorgrades nicht vorliegt.

München, den 30. September 2008

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List of Abbreviations

AFIR	Actuarial Approach for Financial Risks
AR	Autoregressive
ARCH	Autoregressive Conditional Heteroscedasticity
Ave. Earn.	Average Hourly Earnings
bps	Basis Points
Bus. Conf.	Business Confidence
Bus. Inv.	Business Inventories
Cap. Util.	Capacity Utilisation
Cons. Conf.	Consumer Confidence of Conference Board
CPI	Consumer Price Index
CPI Fl.	CPI Flash Estimate
CPPI	Constant Proportion Portfolio Insurance
Cur. Acc.	Current Account
Cusum	Cumulative Sum
DAX	Deutscher Aktienindex
Dur. Ord.	Durable Goods Orders
DW	Durbin-Watson
ECB	European Central Bank
ed.	Editor(s)
Emp. St. I.	Empire State Manufacturing Index
EMU	European Economic and Monetary Union
ESI	Economic Sentiment Indicator
Exp.	Exports
FAVAR	Factor-Augmented Vector Autoregressive

Fed	Federal Reserve
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GDP	Gross Domestic Product
GNP	Gross National Product
Help. Wa. I.	Help Wanted Index
HP	Hodrick-Prescott
Hou. Per.	Housing Permits
Hou. Sta.	Housing Starts
Ifo	Ifo Institute for Economic Research
Imp. Pr.	Import Prices
Ini. Clai.	Initial Claims
ISM mfg	Institute for Supply Management, Manufacturing Index
ISM nmfg	Institute for Supply Management, Non-Manufacturing Index
Lead. Ind.	Leading Indicator
MIT	Massachusetts Institute of Technology
mom	Month-on-month
NAIRU	Non-accelerating Inflation Rate of Unemployment
NBER	National Bureau of Economic Research
obs.	Observations
OLS	Ordinary Least Squares
Ord.	Industrial Orders
Payrolls	Non-farm Payrolls
PC	Principal Component
PCE	Personal Consumption Expenditures Price Index
PEH	Pure Expectations Hypothesis
Pers. Exp.	Personal Expenditures
Pers. Inc.	Personal Income
Phil. Ind.	Philadelphia Fed Index
PIMCO	Pacific Investment Management Company
PMI	Purchasing Managers Index

PMI Chic.	Chicago Purchasing Managers Index
PPI	Producer Price Index
Prod.	Industrial Production
qoq	Quarter-on-quarter
Ret.	Retail Sales
Ret. ex. a.	Retail Sales excluding autos
S&P	Standard & Poor's
SUR	Seemingly Unrelated Regression
Tra. Bal.	Trade Balance
Une.-ploy.	Unemployed
Une. Rate	Unemployment Rate
Unit Lab. Co.	Unit Labour Costs
Univ. of Mich.	University of Michigan, Consumer Confidence
US	United States of America
VAR	Vector Autoregression
Vehi. Sal.	Vehicle Sales
yoy	Year-on-year
ZEW	Centre for European Economic Research

Chapter 1

The Term Structure of Interest Rates

1.1 Financial Markets and the Real Economy

The linkages between interest rates in financial markets and their effects on consumption, investment and saving in the real economy are based on Macroeconomic theory (Burda and Wyplosz (1997)). In recent years, the significant bidirectional effects between financial markets and the real economy have experienced an increase in attention in the literature on Macroeconomics, Financial Economics and Finance. Many articles relate macroeconomic conditions to asset prices in financial markets and vice versa. For example, Ludvigson and Steindel (1999) research on the effect of the stock market on consumption and Lettau and Ludvigson (2004) on the effect of wealth on consumption. The Dividend Discount model explains the current stock price as the present value of future dividends discounted with an appropriate interest rate (Ross, Westerfield and Jaffe (2002)), whereas future dividends and the discount rate depend on future real economic activity. Taylor (1993) relates output and inflation in a monetary policy rule to the target interest rate, which determines prices in financial markets for short term bonds. Long term interest rates are also influenced by current and expected monetary policy. According to the Pure Expectations Hypothesis (section 1.3.3), the long term interest rate is the average of expected short term interest rates (Campbell, Lo and MacKinlay

(1997)). Consequently, expectations of the path of the macroeconomy in terms of output and inflation determine the prices in financial markets for long term bonds. Even though there are feedback effects between the real economy and financial markets, much research concentrates on one direction of the effect (partial analysis).

Due to the impact of financial markets on the real economy, central banks monitor financial markets in order to reach their aims of stable prices and a moderate growth of the economy. Both goals can be jeopardized by asset prices that significantly differ from their fundamental or fair values (asset price bubble). Bernanke and Gertler (1999) argue that the central bank should only react to changes of asset prices when asset prices affect inflation. In contrast to that, Cecchetti, Genberg and Wadhwani (2002) argue that a central bank is able to detect an asset price bubble in advance and should react in order to achieve the inflation target and to minimize the negative impact on the real economy.

Effects from financial markets on the real economy are of interest for policy makers who try to enable steady and sustainable growth of the economy. Therefore, financial market regulation which is based on prudent macroeconomic considerations is necessary (Borio (2003)). Furthermore, the regulation of financial institutions and financial markets is important in situations of financial distress. Regulatory issues should prevent a decrease in the real economy due to shocks to the financial system.[1] Historical examples provide empirical evidence for financial crisis that cause a loss in welfare due to the severe decrease in output. For example, Argentina's economy suffered from a debt crisis, East Asian economies from currency crisis and Japan's economy from a banking crisis. The aftermaths of financial crisis showed the need for the understanding of financial stability and appropriate regulatory frameworks of the financial system.

A very recent example for feedback effects between financial markets and the real economy is the current crisis in financial markets since summer 2007. Foremost in the US, higher interest rates of corporate bonds and higher short term lending rates in the interbank market distorted the efficient capital allocation. Hence, investment opportunities were not realized, which caused a loss in welfare in the short term (consumption) and in the long term (potential growth rate of the real economy).

[1]The costs of banking crises are quantified by Hoggarth, Reis and Saporta (2001). The seminal article for bank runs that cause real economic damage is Diamond and Dybvig (1983).

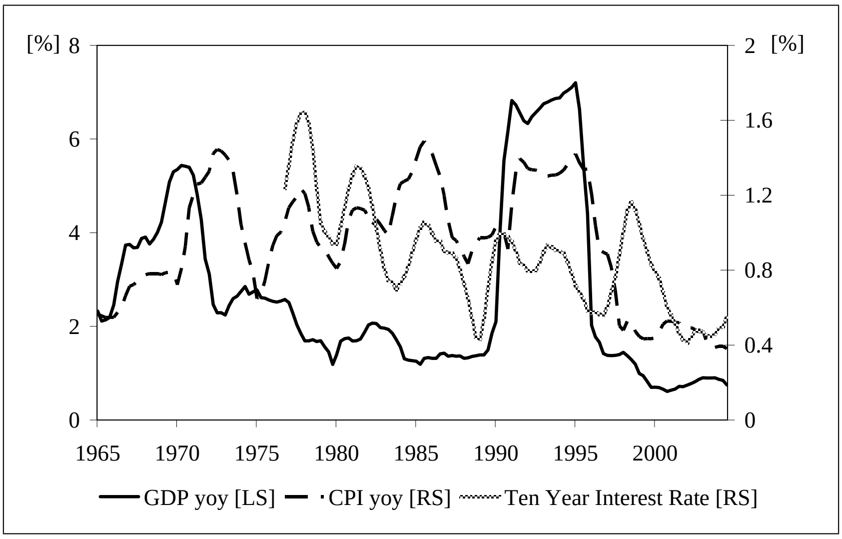

Figure 1.1: 20-quarter moving standard deviation of year-on-year growth rate of GDP (seasonally adjusted), of quarterly average of year-on-year change of CPI (seasonally adjusted) and of quarterly average of ten-year interest rate (government bond). Source: Global Insight (GDP and CPI) and Deutsche Bundesbank (ten-year interest rate).

The effects of financial markets on the real economy have been briefly summarized in the last lines. In contrast to that, this thesis mainly analyses the effect of the real economy on financial markets. Due to the fact that financial markets are based on expectations which are uncertain, the magnitude of the uncertainty about the future path of the economy is an important driver of financial markets. The uncertainty of the expectations of the macroeconomy can be measured by the realized macroeconomic volatility, for example by a 20-quarter moving standard deviation. Appropriate variables to quantify the realized volatility of an economy are: the Gross Domestic Product (GDP) as a measure of real economic activity, the Consumer Price Index (CPI) as an indicator for the price level and the long term interest rate (for example the yield of a government bond with a time to maturity of ten years).[2]

Figure 1.1 shows the 20-quarter moving standard deviation of these variables for Germany.[3] The moving standard deviation of GDP growth year-on-year (yoy) has a higher realized volatility than CPI growth yoy and the long term interest rate. The standard deviation of GDP started to decline in the 1970s and increased significantly

[2]In this thesis, “time to maturity” is often abbreviated with “maturity”.

[3]The time series of the 20-quarter moving standard deviation for German GDP and CPI begin in 1965 and for the ten-year interest rate in 1977.

for six years after the German reunification. Afterwards, it declined to the lowest level during the sample. The standard deviation of the CPI growth fluctuated around one until the German reunification and shows a similar pattern to the GDP growth afterwards. The realized volatility of the long term interest rate has also a downward trend during the sample. However, it was not influenced by the German reunification.

The lower realized volatility of GDP, CPI and the long term interest rate in Germany in the recent past implies a lower uncertainty in the real economy and a lower uncertainty in financial markets. During the sample, the downward trend of the volatility of GDP is due to a strong economic development and the downward trend of the volatility of the CPI is due to the low inflation rate based on the monetary policy of the Deutsche Bundesbank. As asset prices depend on the investors' perception of risk, the lower historical uncertainty reduces the expected uncertainty and therefore lowers the risk premium demanded by investors to compensate the higher risk when holding long term assets. Hence, macroeconomic uncertainty influences asset prices in financial markets.[4]

The following sections deal with the relationship between real economic activity and the term structure of interest rates (section 1.2), theories of the term structure of interest rates (section 1.3) and Affine models of the term structure of interest rates (section 1.4).

1.2 The Term Structure of Interest Rates and the Real Economy

One of the bidirectional linkages between the real economy and financial markets is the interdependence between the business cycle and the term structure of interest rates.[5] Both affect each other, but according to the research by Diebold, Rudebusch and Aruoba (2005), the impact of the macroeconomy on the term structure of interest rates is more powerful.

According to economic theory, the shape of the term structure of interest rates has significant linkages with the business cycle. An upward sloping yield curve, i.e. long

[4]A lower risk premium because of reduced past and expected macroeconomic volatility is one explanation for Greenspan's conundrum (section 1.2).

[5]The terms "term structure of interest rates" and "yield curve" are used interchangeable.

term yields are higher than short term yields, is signalling a currently low economic growth and an expected upswing of the economy. The reason for the low short term interest rate is that the central bank stimulates the economy with a low target rate due to the low or even negative growth rate of the economy. The reason for the high long term interest rate is that investors expect the economy to grow faster in following periods because of the time lag until monetary policy stimulates real economic activity. These positive expectations of the economy increase long term yields for two reasons: first, a strong economy has a large demand for capital. Therefore, an increasing supply of bonds reduces the prices of long term bonds and consequently increases yields of long term bonds. Second, an economy at the peak of the business cycle has a high demand for goods and services. Hence, capacity utilisation rises and causes upward pressure on the price level. As a consequence, the central bank starts to increase the target rate what in turn causes the short term interest rate to increase, too. The expected increase in future short term interest rates affects today's prices of long term bonds because of arbitrage in financial markets. For example, in order to make investors willing to buy a long term bond today rather than buying a short term bond today and buying a long term bond in the next period when yields are higher, they have to be compensated by higher yields for the long term investment today.

When the yield curve is flat, yields for all maturities have the same level as short term interest rates are unusually high and long term interest rates unusually low. A flat yield curve implies that current GDP growth is modest whereas a downswing of the economy is expected in the medium term. The reason why the short end of the yield curve is above average is the restrictive monetary policy in order to prevent the economy from overheating. Therefore, market participants expect a decline in future GDP growth which reduces inflationary pressure and the demand for capital. An inverse term structure of interest rates, i.e. short term yields are higher than long term yields, implies an even more pronounced downswing of the real economy in the medium term than a flat yield curve. In the past, an inverse yield curve has been a reliable indicator for a recession.

A discussion of the relationship between the shape of the yield curve and the business cycle can be found in Fama (1990). Fama identifies business cycles according to the definition of the National Bureau of Economic Research (NBER) between 1952 and 1988 and compares different economic situations with the term spread between interest rates of a five-year and a one-year bond. He concludes that short term interest rates are pro-cyclical, i.e. short term interest rates are lower at the trough of the business cycle than at the peak. In contrast to that, the term spread between a five-year and a one-year bond behaves counter-cyclically. The term spread is high (the yield curve is steep) at the trough of the business cycle and the term spread is low (the yield curve is flat) at the peak of the business cycle.

A recent issue of the bidirectional effects between the term structure of interest rates and the real economy is Alan Greenspan's conundrum: Alan Greenspan, then chairman of the Federal Reserve, stated in February 2005 that the low level of long term interest rates is a conundrum to him. Although the Federal Reserve has raised the Fed's target rate from 1% in June 2004 in continuous steps of 25 basis points (bps) to 3.25% in July 2005, interest rates of long term US Treasuries have declined since the beginning of the monetary tightening. During the tightening cycle, the increases in the Fed's target rate have been nearly pre-announced and further steps have been expected even after July 2005.[6] As these expectations of higher short term interest rates should result in higher long term interest rates according to the Expectations Hypothesis, the actual decline of long term interest rates is a contradiction to the Expectations Hypothesis.[7]

Figure 1.2 shows the yield curve of US Government securities in May 2004 and in July 2005 in order to illustrate the conundrum. The yield curve was upward sloping in May 2004, before the Fed started to raise the target rate in order to reduce monetary stimulus, and the yield curve was basically flat in July 2005. Therefore, short term interest rates increased and long term interest rates decreased during this period. The increase in short term yields is in line with economic theory. In contrast to that, the decrease in long term interest rates is a contradiction to the Expectations Hypothesis, because further increases in the Fed's target rate to a neutral level were expected.

[6] During the tightening cycle of the Federal Reserve, the Federal Open Market Committee statement usually included the wording "... the Committee believes that policy accommodation can be removed at a pace that is likely to be measured."

[7] The Expectations Hypothesis states that long term interest rates are the average of current and future expected short term interest rates (section 1.3.3).

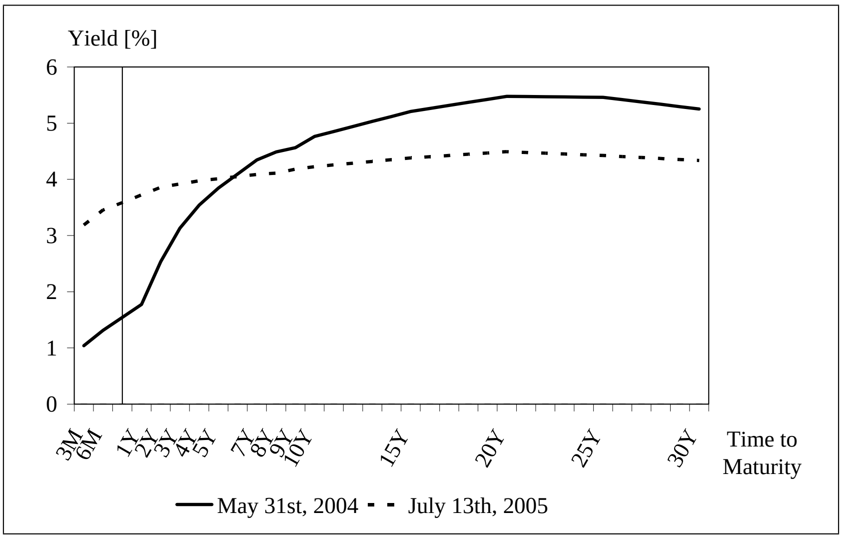

Figure 1.2: Term structure of interest rates for US government bonds before and after the Federal Reserve started to tighten monetary policy in 2004. Source: Bloomberg.

Central bankers and market participants try to explain the surprising decrease in long term interest rates and the flattening of the yield curve. A possible reason for the low level of long term interest rates is an increase in the demand for US long term bonds which resulted in higher prices and lower long term interest rates. According to Bernanke (2005), the global "saving glut", which flooded global capital markets, may have increased the demand for long term US Treasuries. Since the end of the 1990s, emerging economies have been net savers, i.e. capital exporters. In addition to that, some Asian central banks tried to hold the foreign exchange rate of their currency against the US Dollar at a certain level and bought US Treasuries. The large amount of "petro dollars", i.e. high revenues of oil exporting countries due to a high oil price (Higgins, Klitgaard and Lerman (2006) and Toloui (2007)), and ageing industrial societies seeking for old-age provisions might be other reasons for a structurally higher demand for long term US Treasuries.

Another explanation of the conundrum is given by Rudebusch, Swanson and Wu (2006) who use a no-arbitrage Macro-Finance model of the term structure of interest rates and find that this model cannot explain the unusually low level of long term interest rates. Hence, they propose that the decline in the volatility of long term interest rates has caused the low level of long term interest rates. Alternatively, some explanations of the conundrum are based on monetary policy. Before the conundrum, all main central banks held short term interest rates at a low level and contributed to excess liquidity, which caused upward pressure on prices of long term bonds. Furthermore, the high credibility of central banks in the US and in the euro area might have reduced inflation expectations and the inflation risk premium, which yields a significant decline in the nominal long term interest rate.

A change of the structure of the US and global economy might also explain the unusually low level of long term interest rates. The global positive supply shock (an increased supply of labour) might have flattened the US Phillips curve which relates a given level of GDP growth to a lower level of inflation and consequently to a lower level of long term interest rates. Besides, lower expectations of long term GDP growth (potential growth) of the US economy might have resulted in lower real interest rates and consequently lower nominal long term interest rates. Another reason for the conundrum might be the global high level of firms' earnings which enabled firms to invest without borrowing in debt markets. This self financing of investments reduced the supply of bonds and therefore lowered the level of long term interest rates. Up to now, there is no conclusion in the academic literature on the reason for the conundrum.

1.3 Economic Theory

1.3.1 Stylized Facts

The term structure of interest rates relates interest rates to their time to maturity of similar bonds at one point in time (cross-sectional).[8] In the literature, these interest rates often refer to default-free bonds (government bonds of rich countries with an excellent credit rating). The most common forms of the yield curve are upward sloping, flat or inverse (figure 1.3, whereas the level of interest rates has no meaning).[9] Figure 1.4 is a three dimensional plot of the German term structure of interest rates.

[8] Shiller (1990) presents a comprehensive description and theories of the term structure of interest rates.

[9] Also U- and hump-shaped yield curves can be observed and yield curves with more than one tale or peak (for example spoon-shaped yield curves).

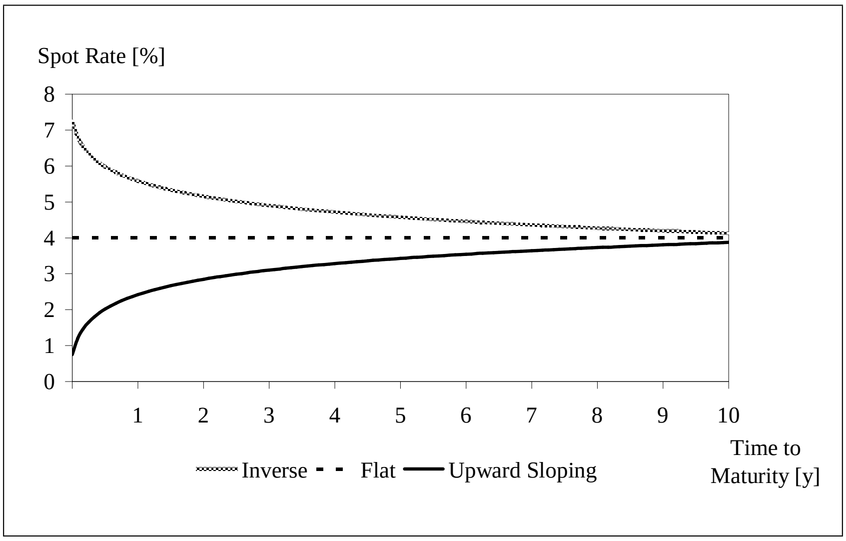

Figure 1.3: Different shapes of the yield curve.

One possibility to generate the term structure of interest rates is to use the yield to maturity of bonds, because the yield to maturity can be calculated with market data of coupon bonds. The yield to maturity of a bond is the constant discount rate which equates today's price with the present value of the future cash flows until maturity (Campbell, Lo and MacKinlay (1997)).[10] Another possibility is to use the spot rate, which is the yield to maturity of a zero-coupon bond. To calculate spot rates from coupon bonds, every coupon bond can be seen as a portfolio of hypothetical zero-coupon bonds. As the prices and spot rates of the hypothetical zero-coupon bonds are unknown, the spot rates can be estimated by an iterative procedure based on market data of coupon bonds (Deutsche Bundesbank (1997)). Due to the limited availability of coupon bonds, it is not possible to obtain an interest rate for every time to maturity. Accordingly, it is necessary to interpolate between known interest rates, to use parametric methods (Nelson and Siegel (1987) and Svensson (1995)) or to use spline based methods (McCulloch (1971)).

In the following lines, economic theories of the term structure of interest rates are described. Section 1.3.2 covers the Fisher Identity, section 1.3.3 the Expectations Hypothesis and section 1.3.4 the Stochastic Discount Factor.

[10]The calculation of the yield to maturity of a coupon bond assumes that all coupon payments can be re-invested at the calculated yield to maturity.

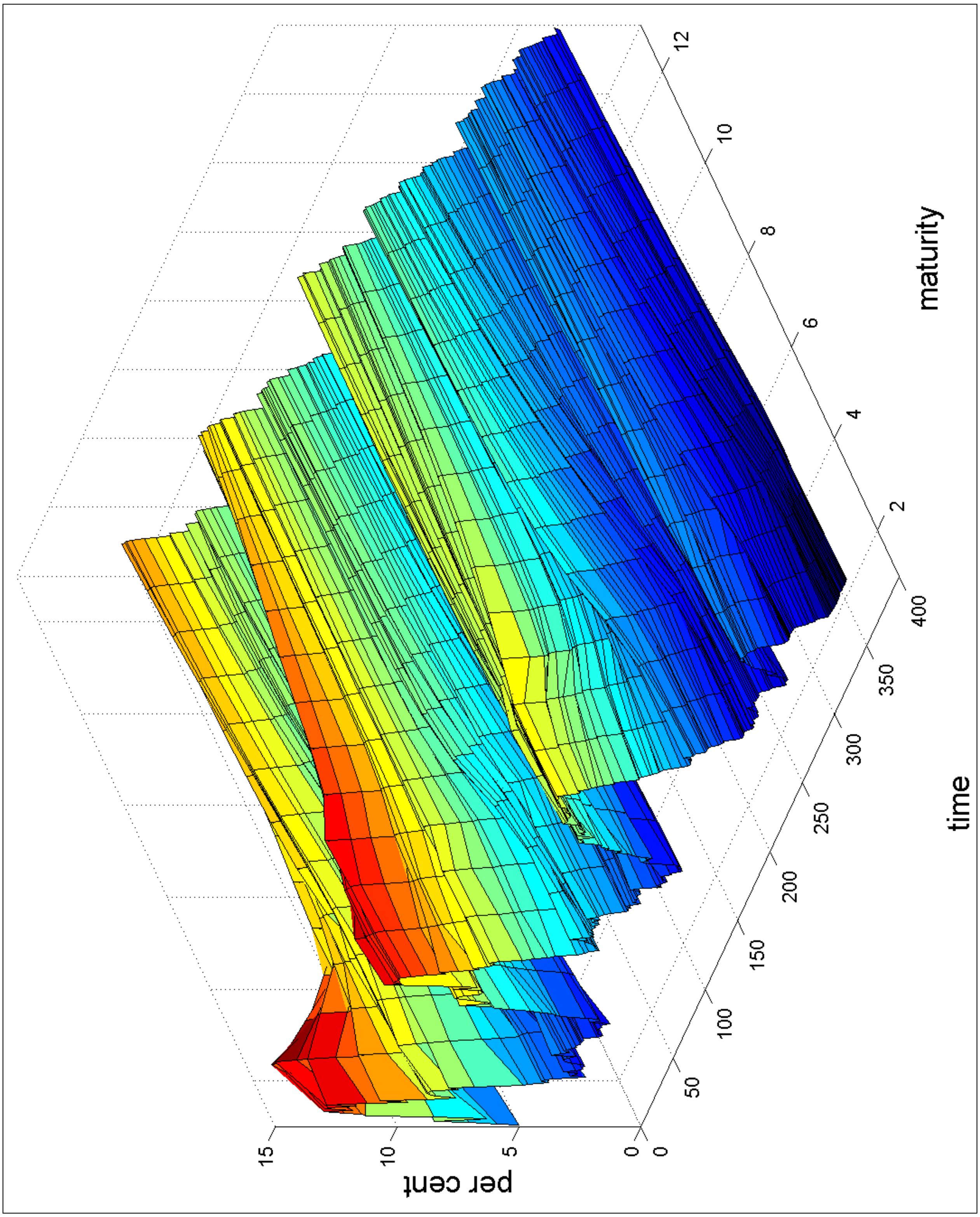

Figure 1.4: Three-dimensional plot of the German yield curve (end of month data) between September 1972 and October 2005 (398 monthly observations for each maturity). The figure plots money market interest rates for one, three and six months (1 to 3) and yields of zero-coupon bonds for maturities between one and ten years (4 to 13). Source: Deutsche Bundesbank.

1.3.2 Fisher Identity

The Fisher Identity relates the nominal interest rate i to the sum of the real interest rate r and the ex ante expected inflation rate $E[\pi]$,

$$i = r + E[\pi]. \tag{1.1}$$

The Fisher Identity has implications for the linkage between financial markets and the real economy by the "Fisher Effect" (Romer (2001)). Under the assumption that the inflation rate and real interest rate are independent, equation 1.1 implies that an increase in the expected inflation rate results in a higher nominal interest rate by the same amount. The Fisher Effect has been subject to a lot of empirical studies (James and Webber (2000) give an overview of empirical tests of the Fisher Effect).

Based on equation 1.1, Fama (1975) relates short term interest rates to inflation and researches on the magnitude of the effect of the real interest rate and expected inflation on the short term nominal interest rate. He concludes that the main determinant of the nominal short term interest rate is a change of expected inflation and not a change of the real interest rate. The effects of inflation expectations and the real interest rate on the nominal short term interest rate are empirically modelled in section 2.4.3 by a Taylor rule of monetary policy.[11]

1.3.3 Expectations Hypothesis

The fundamental economic theory which connects short and long term interest rates is the Expectations Hypothesis. The Expectations Hypothesis deals with a long term investment decision in the fixed income market. One possibility is to buy a bond that has a long term maturity. The other possibility is to buy a one-period bond in every successive period until the end of the investment horizon (Ross, Westerfield and Jaffe (2002)). The investor is indifferent between holding one long term bond until maturity and rolling over a sequence of one-period bonds, if the expected return of both investment strategies is the same. This is the foundation of the Pure Expectations Hypothesis which

[11] Wu (2006) describes the relationship between main macroeconomic variables and the long term interest rate based on the Fisher equation.

states that long term interest rates are the average of expected future short term interest rates. The Pure Expectations Hypothesis neglects risk aversion and liquidity preference of an investor. In contrast to that, the Expectations Hypothesis includes a term premium due to risk aversion, liquidity preference or preferred habitat of investors.

A large number of empirical articles researches on the Expectations Hypothesis. A survey is given by Cook and Hahn (1990) and Ichiue (2004). Even though the empirical validity of the Expectations Hypothesis is not generally accepted in the literature, the Expectations Hypothesis is the working assumption in Financial Economics. Lutz (1940) relates the following empirical characteristics of the yield curve to the Expectations Hypothesis: a higher variance of short term interest rates than of long term interest rates (table 2.2), a negative correlation of short and long term interest rates and an upward sloping yield curve.

As the Pure Expectations Hypothesis assumes that investors are risk neutral and do not demand a risk premium for their willingness to hold long term assets, the expected excess return of long term bonds over short term bonds is equal to zero. The Pure Expectations Hypothesis has two forms, the one-period and the n-period form (Campbell, Lo and MacKinlay (1997)). The one-period Pure Expectations Hypothesis focuses on the return in the next period of a one-period bond and an n-period bond. The one-period bond is bought at time t and held until maturity, whereas the n-period bond is bought at time t and sold as a bond with a maturity of $n-1$ at time $t+1$. The one-period Pure Expectations Hypothesis states that at time t, the known return of a one-period bond is equal to the expected return in the next period of an n-period bond. In contrast to that, the n-period Pure Expectations Hypothesis focuses on the expected return of the next n periods and states that at time t, the expected return of rolling over one-period bonds during the next n periods is equal to the known return of buying an n-period bond at time t and holding it until maturity.[12]

The Pure Expectations Hypothesis can also be formulated in terms of the forward rate and the expected spot rate (appendix A.1) and is defined as the equality of the

[12] Campbell, Lo and MacKinlay (1997) state that the one-period and n-period Pure Expectations Hypothesis cannot hold simultaneously, because interest rates are random variables and therefore Jensen's Inequality applies, i.e. the expectation of the inverse of a random variable is different from the inverse of the expectation of a random variable.

one-period forward rate for time $t+\tau$ at time t ($f(t,\tau)$) and the expectations at time t of the future one-period spot rate at time $t+\tau$ ($E_t[r_{t+\tau}]$). As the Pure Expectations Hypothesis considers risk neutral investors, the forward rate at time t is only determined by the expectation at time t of the one-period spot rate at time $t+\tau$,

$$f(t,\tau) = E_t[r_{t+\tau}]. \tag{1.2}$$

The Expectations Hypothesis is based on the Pure Expectations Hypothesis and augmented by a further term which takes account of risk aversion, liquidity preference or preferred habitat. The Expectations Hypothesis equates the one-period forward rate for time $t+\tau$ at time t ($f(t,\tau)$) and the sum of the expectation at time t of the future one-period spot rate at time $t+\tau$ ($E_t[r_{t+\tau}]$) and a constant premium b_τ,

$$f(t,\tau) = E_t[r_{t+\tau}] + b_\tau. \tag{1.3}$$

If the premium is positive, the expected return of a long term bond is higher than rolling over short term bonds because of the investor's gain of the premium (Gibson, Lhabitant and Talay (2001)). If risk aversion or liquidity preference are taken into account, the constant b_τ is strictly greater than zero for $\tau > 0$. Hence, the one-period forward rate $f(t,\tau)$ is higher than the expected one-period spot rate $E_t[r_{t+\tau}]$ (Hicks (1946)[13]). Equation 1.3 implies that b_τ is increasing with τ and that the term structure of interest rates is always upward sloping. As there are other observed shapes of the yield curve (downward sloping, flat, inverse and hump-shaped), additional theories are necessary.

If the Market Segmentation Hypothesis or Preferred Habit theory are included in the Expectations Hypothesis, the sign of the constant b_τ is not restricted for $\tau > 0$. According to the Market Segmentation Hypothesis, the price of a bond with a certain maturity only depends on its demand and supply and is independent of demand and supply of bonds with other maturities (Culbertson (1957)[14]). So, arbitrage is not taken

[13] Cox, Ingersoll and Ross (1985a) quote Hicks, J. R., 1946, Value and Capital, 2nd edition, Oxford University Press, London.

[14] Cox, Ingersoll and Ross (1985a) quote Culbertson, J. M., 1957, The Term Structure of Interest Rates, Quarterly Journal of Economics, 71, 485-517.

into account by the Market Segmentation Hypothesis. The Preferred Habit theory assumes that investors are willing to buy bonds of maturities other than their most preferred maturity, if they are compensated for it (Modigliani and Sutch (1966)[15]). Both theories allow for a negative b_τ, because investors are willing to accept a lower yield for a bond with their preferred time to maturity.

The implications of the Expectations Hypothesis for the bidirectional effects between the macroeconomy and the yield curve are strong. The reason is that macroeconomic variables (inflation and output) affect the decision of the central bank concerning the short term interest rate. Therefore, it is important to consider how the central bank reacts to the current and expected path of output and inflation when modelling the term structure of interest rates by macroeconomic theory (section 2.4.3). Furthermore, the current short term interest rate and expected short term interest rates (due to expected inflation and output) are translated by the Expectations Hypothesis into the current long term interest rate. The long term interest rate influences the aggregate demand in an economy via savings and investments (Piazzesi (2003)). Therefore, the Expectations Hypothesis indicates how current monetary policy affects the long term interest rate and the real economy in the future.[16]

1.3.4 Stochastic Discount Factor

Another approach which is used in Finance and Economics to explain the term structure of interest rates is the Stochastic Discount Factor. Given an intertemporal utility maximizing investor, the Stochastic Discount Factor displays the intertemporal marginal rate of substitution between consumption today and in a future period. According to the intertemporal utility maximization, the investor demands a risk adjusted return and hence determines the price of the asset. The Stochastic Discount Factor is part of the consumption based asset pricing equation (Euler equation) that solves the investor's optimisation problem concerning decisions on consumption and portfolio holdings (Camp-

[15]Cox, Ingersoll and Ross (1985a) quote Modigliani, F. and R. Sutch, 1966, Innovations in Interest Rate Policy, American Economic Review, 56, 178-197.

[16]In emerging markets, the central bank might have a lower impact on the real economy if capital markets are less developed.

bell, Lo and MacKinlay (1997)). The Stochastic Discount Factor is criticized due to its rigorous assumptions: the utility function of the investor has to be constant over time, the maximization of the utility of the investor only depends on consumption and on the discount factor and the investor has no restrictions for investments in financial markets.

According to the concept of the Stochastic Discount Factor, an individual investor accepts a lower return (higher price) of an asset if the cash flows are paid in periods when the investor has a high marginal utility of consumption (high Stochastic Discount Factor).[17] Consequently, the expected risk adjusted return of a risky asset depends on the correlation of the return of the risky asset and the individual Stochastic Discount Factor. If the correlation is positive, the risky asset pays high cash flows when the marginal utility of consumption is high. Hence, the investor is willing to pay a higher price for the asset and is willing to accept a lower risk premium. If the correlation is negative, the investor risks receiving low cash flows from the risky asset when the marginal utility of consumption is high. As a consequence, the investor demands a high risk premium for the willingness to hold the risky asset (and is only willing to pay a low price for the asset).

In period $t+1$, the Stochastic Discount Factor M_{t+1} is defined as

$$M_{t+1} = \delta \frac{U'(C_{t+1})}{U'(C_t)}, \tag{1.4}$$

where δ is the time discount factor and $U'(C_t)$ the marginal utility of consumption C in period t (Campbell, Lo and MacKinlay (1997)). The general asset pricing condition is[18]

$$1 = E_t[(1 + R_{i,t+1})M_{t+1}], \tag{1.5}$$

where $R_{i,t+1}$ denotes the real return of the risky asset i in the next period (t+1).[19] Hence,

[17]This might be the case when an investor is saving for the period after retirement in which the marginal utility of consumption will be higher due to a lower level of consumption.

[18]As the Stochastic Discount Factor is based on consumption, the general asset pricing condition applies to real asset returns. Campbell, Lo and MacKinlay (1997) augment the concept of the Stochastic Discount Factor by a nominal price index and construct a Nominal Stochastic Discount Factor to price nominal assets.

[19]Equation 1.5 results, if the first-order condition (Euler equation) of the optimal decision of the investor between consumption and investment $U\prime(C_t) = \delta E_t[(1 + R_{i,t+1})U\prime(C_{t+1})]$ is

the expected return of a riskfree asset $R_{0,t}$ is given by $E_t[1+R_{0t}] = 1/E_t[M_t]$, because the expected return of a riskfree asset is uncorrelated with the Stochastic Discount Factor ($Cov[R_{0t}, M_t] = 0$). The expected excess return of a risky asset $E_t[Z_{it}]$ is given by $E_t[Z_{it}] = E_t[R_{it} - R_{0t}]$. Using equation 1.5 and its application to the return of a riskfree asset yields the expected excess return of a risky asset which depends on the expected return of a riskfree asset R_{0t} and on the covariance of the return of the risky asset $R_{i,t}$ and the Stochastic Discount Factor M_t,

$$E_t[Z_{it}] = -E_t[1 + R_{0t}] \cdot Cov[R_{it}, M_t]. \tag{1.6}$$

Equation 1.6 implies a negative relationship between the expected excess return of a risky asset and the covariance of the return of the risky asset and the Stochastic Discount Factor. Therefore, the expected return of a risky asset is the larger (lower) the lower (larger) its covariance with the Stochastic Discount Factor.

The Stochastic Discount Factor can be used to model the term structure of interest rates. The reason is that equation 1.6 determines the price of a fixed income asset depending on the covariance between the return of the fixed income asset and the Stochastic Discount Factor. As the cash flows of the fixed income security are deterministic, the covariance of the return of the fixed income asset and the Stochastic Discount Factor only changes if the discount rate, which is applied to coupon payments and the face value, changes. The change of the discount rate is due to a change of the Stochastic Discount Factor. Consequently, a time series model of the Stochastic Discount Factor is a model of the term structure of interest rates. The Stochastic Discount Factor is often used to determine the price of fixed income assets, because it can be augmented to impose the no-arbitrage condition (section 2.2).

1.4 Affine Models

Cochrane (2001) distinguishes between two different ways in Finance to model asset prices. In absolute asset pricing models (for example consumption-based and general

divided by $U\prime(C_t)$ (Campbell, Lo and MacKinlay (1997)).

equilibrium models), the price of the asset is determined by the exposure of the asset to its fundamental macroeconomic risk. The approach is positive as it tries to explain the reasons of changes in the level and return of the asset price. Hence, absolute asset pricing can be used to forecast asset prices based on the future macroeconomic situation. In relative asset pricing models (for example no-arbitrage models), the price of an asset is only determined by the prices of other (reference) assets, which are taken as exogenous. Consequently, the fundamental sources of the price of the reference assets are not directly taken into account. Nevertheless, this approach to relative asset pricing is sufficiently precise in practical applications.[20]

There are many different models – both absolute and relative pricing models – available to describe and forecast the dynamics of the term structure of interest rates.[21] In Finance, affine models of the term structure of interest rates are used because of their tractability and flexibility. In affine models of the term structure of interest rates, bond prices or yields with different maturities are an affine (constant plus linear) function of the state vector, which often is the short term interest rate. One of the first affine term structure models is Vasicek (1977). Other seminal articles are Cox, Ingersoll and Ross (1985b), Longstaff and Schwartz (1992) and Hull and White (1993). Dai and Singleton (1998) classify affine models and Duffie and Kan (1996) provide a theory for affine models of the term structure.

It is useful to consider affine models of the yield curve as a state space system (Piazzesi (2003)). The state space system consists of the observation equation (measurement equation) that establishes a relationship between observable yields and one or more state variables, and the state equation (transition equation) that characterises the dynamics of the state variables. There are two different kinds of state variables: they can be directly observable, i.e. historical and contemporaneous financial market

[20] Copeland, Weston and Shastri (2005) divide models of the term structure of interest rates in equilibrium models (absolute asset pricing) and no-arbitrage models (relative asset pricing). In equilibrium models, interest rates are explained by the macroeconomy. Hence, there may be periods when the interest rate given by the model significantly deviates from the interest rate observed in the financial market. In contrast to that, no-arbitrage models generate interest rates that are close to the interest rates observed in the market, but ignore the macroeconomic factors of the asset price.

[21] James and Webber (2000) give an overview of term structure models.

or macroeconomic data, or they can be latent or unobservable, i.e. they have to be modelled. Due to the purely statistical characteristics of an affine model, it neglects macroeconomic aspects when explaining interest rates. Therefore, the Macro-Finance approach to model the term structure of interest rates came up in the recent past. In this new approach, methods used in Finance and Macroeconomics are combined to model the term structure of interest rates. The inclusion of observable macroeconomic variables in the state vector allows incorporating macroeconomic information into affine models of the yield curve.

A subclass of affine models of the term structure of interest rates is (latent) factor models. They can be derived from affine models of the term structure of interest rates under some assumptions.[22] The seminal paper for latent factor models is Nelson and Siegel (1987). In a one-factor model, the state vector is a scalar, whereas in a multi-factor model, the state vector consists of a limited number of factors. The factors used in the models may be observable or latent. Advantages of factor models are their good ability to match empirical data as well as their usage for pricing derivatives.

Most of the term structure models used in Finance can be used in discrete or continuous time. This section discusses models of the term structure of interest rates in discrete time. The reason is that the empirical macroeconomic model presented in chapter 2 is estimated by monthly macroeconomic data. The following discussion of three widespread affine models of interest rates is based on Backus, Foresi and Telmer (1998).

1.4.1 Duffie and Kan Models

Duffie and Kan (1996) present a theoretical framework for affine term structure models and formulate the process of the vector of state variables. They show that it is possible to use yields of zero-coupon bonds as state variables in an affine model of the term structure of interest rates. Consequently, it is possible to calibrate the affine term structure model to a set of spot rates, for example with time to maturities of three months, two years and ten years (James and Webber (2000)). The Duffie and Kan model assumes that the

[22]Details for these assumptions can be found in Stambaugh (1988) and Heston, S., 1992, Testing Continuous-Time Models of the Term Structure of Interest Rates, unpublished paper, Yale University, which is quoted by Campbell, Lo and MacKinlay (1997).

price of an n-period bond is exponentially affine in the state vector X_t, which is a set of spot rates. In equation 1.7, the yield y_t^n of a bond with a time to maturity n at time t is an affine function of the state vector X_t and of the parameters A_n and B_n which depend on the time to maturity n,

$$y_t^n = \frac{1}{n}(A_n + B_n' X_t). \tag{1.7}$$

In contrast to the Duffie and Kan model which is a multi-factor model as the state vector consists of a set of spot rates, there also exist affine one-factor models of the term structure of interest rates. In a one-factor model, the interest rate of a certain maturity is only explained by one state variable which is often the short term interest rate. Hence, the single factor contains all information about the term structure of interest rates at one point in time, because the state equation specifies the process for the single factor and the observation equation explains the yield of a certain maturity by the single factor.

1.4.2 Vasicek Models

Regardless whether the affine model of the term structure of interest rates is a one-factor or a multi-factor model, the class of affine models can be divided according to the characteristics of the volatility in the process of the state vector. In the following lines, the Vasicek and the Cox, Ingersoll and Ross models are presented in a one-factor formulation.[23]

The typical characteristic of a Vasicek affine model is the constant volatility of the state variables, i.e. the process of the state variables has a constant variance σ^2, which is normally distributed.[24] Vasicek (1977) uses a first-order autoregression for the process of the short term interest rate r_t at time t,

$$r_t = \phi r_{t-1} + (1-\phi)\theta + \varepsilon_t, \quad \text{with } \varepsilon_t \sim N(0, \sigma^2), \tag{1.8}$$

[23]Both the one-factor Vasicek model and the one-factor Cox, Ingersoll and Ross model can be extended to multi-factor models (Backus, Foresi and Telmer (1998)).

[24]Due to the normal distribution of the variance in the Vasicek model, it is also known as a Gaussian model.

where θ is the mean of r. The parameter ϕ determines the mean reversion of the process. If $\phi = 1$, the process of the short term interest rate (equation 1.8) follows a random walk and is not mean reverting. If $0 < \phi < 1$, the short term interest rate is mean reverting, which is the central property of the model. Another formulation of the Vasicek model is equation 1.9. If the actual short term interest rate r_t is larger than its mean θ, the expected change of r_t is negative. The expected change of r_t is positive, if r_t is lower than θ. The adjustment speed of the mean reversion of r_t is $(1 - \phi)$,

$$r_t = r_{t-1} + (1 - \phi)(\theta - r_{t-1}) + \varepsilon_t, \quad \text{with } \varepsilon_t \sim N(0, \sigma^2). \tag{1.9}$$

The mean reversion in the Vasicek model reduces the probability of exceptionally high or low short term interest rates. However, the short term interest rate can become negative which is contradictory to economic theory of nominal interest rates. Another problem of the Vasicek model is that it assumes a constant risk premium and can therefore only explain monotone shapes of the yield curve.

1.4.3 Cox, Ingersoll and Ross Models

Another affine term structure model is due to Cox, Ingersoll and Ross (1985b). They formulate the process of the short term interest rate with an equilibrium model, where individuals maximise their logarithmic utility function. Both Vasicek and Cox, Ingersoll and Ross model the short term interest rate time invariant and normally distributed (due to the normally distributed error term). In contrast to the Vasicek model, the Cox, Ingersoll and Ross model replaces the constant variance by a state dependent variance,

$$r_t = (1 - \phi)\theta + \phi r_{t-1} + \sqrt{r_{t-1}}\varepsilon_t, \quad \text{with } \varepsilon_t \sim N(0, \sigma^2). \tag{1.10}$$

The short term interest rate r_t at time t depends on its mean θ, the mean reversion parameter ϕ and the variance, which is state dependent ($\sqrt{r_{t-1}}\varepsilon_t$). The process of the short term interest rate guarantees that the short term interest rate is strictly positive and that the variance of the short term interest rate is not constant but depends on the value of the short term interest rate in the period before.

Chapter 2

Macroeconomic Determinants of the Yield Curve

"I used to think if there was reincarnation I wanted
to come back as the president or the pope ...
but now I want to come back as the bond market.
You can intimidate everybody."

— James Carville, Political Advisor to President Clinton (Economist (2005))

2.1 Macro-Finance Models

Macro-Finance models explain the term structure of interest rates with macroeconomic variables. As macroeconomic variables depend on interest rates, Macro-Finance models consider the bidirectional effects between the real economy and the term structure of interest rates. The analysis in this chapter has a medium term perspective. The short term effects of the macroeconomy on the yield curve are analysed in an event study in chapter 3.[1]

Macro-Finance models of the term structure of interest rates combine a Finance based approach and a Macroeconomics based approach. The Finance based approach uses a latent factor to explain the short term interest rate which determines the term structure of interest rates (section 1.4). Often, interest rates with longer maturities are related to the short term interest rate by the no-arbitrage condition. The Macroeconomics based approach uses macroeconomic models to explain the term structure of interest rates. According to macroeconomic theory, the central bank sets the short term interest rate depending on the price level and the output of the economy. As the long term interest rate can be interpreted as the average of expected short term interest rates (Expectations Hypothesis), the expectations of the future path of the economy influence the expectations of market participants concerning the long term interest rates. Macro-Finance models of the term structure have the advantage that they are parsimonious (parsimony principle), that they take into account linkages between macroeconomic variables and latent factors and that they can incorporate the no-arbitrage condition (Diebold, Piazzesi and Rudebusch (2005)).

Recent Macro-Finance models of the term structure of interest rates have characteristics similar to previous approaches, which are described in the following lines. A lot of research uses the short term interest rate as the only factor to explain the cross-sectional behaviour of the term structure of interest rates. The short term interest rate explains interest rates with longer maturities by the no-arbitrage condition, which is often implemented by the condition of a positive Stochastic Discount Factor (section 2.2).

[1]The bidirectional effects between the real economy and the yield curve in the long term, i.e. according to macroeconomic growth theory, are not included in this thesis.

Mönch (2005) estimates the term structure of interest rates by the short term interest rate, which he can explain with a good fit by a large macroeconomic data set. Mönch concludes that the large set of macroeconomic data can better explain the short end of the term structure than a random walk process. The reason is that the short term interest rate depends on monetary policy and that central bankers consider a large set of macroeconomic indicators for monetary policy decisions.

Rudebusch and Wu (2004a) explain yields of long term bonds by the short term interest rate and the no-arbitrage condition. The short term interest rate is modelled by a Macro-Finance model of the term structure of interest rates in a state space framework. The state variables are two macroeconomic latent factors. The transition equations for the state variables consist of structural macroeconomic equations, because the latent factors, which are commonly used in Finance to model the yield curve, can be related to macroeconomic variables. The level factor can be interpreted as the medium term inflation target of the central bank and the slope factor can be interpreted as the cyclical behaviour of inflation and the output gap. The interpretation of the slope factor is due to the influence of the central bank on the short end of the yield curve in order to reach the goals of monetary policy (reaction function of the central bank). Rudebusch and Wu take into account bidirectional effects between the latent factors of the yield curve and the macroeconomic variables, as inflation and the output gap depend on the yield curve (similar to Diebold, Rudebusch and Aruoba (2005)).

Rudebusch and Wu (2004b) use the Macro-Finance model of Rudebusch and Wu (2004a) to research on structural breaks in the market price of risk in the level factor. They find a structural break in the middle of the 1980s by running Chow tests and Seemingly Unrelated Regressions (SUR). The reason is that investors perceived a lower inflation target of the Fed, which resulted in a lower price of risk in the level factor of the term structure and a decline in the risk premium.

Another research of a no-arbitrage Macro-Finance model of the term structure is Ang and Piazzesi (2003). They explain the short term interest rate by three latent variables and two macroeconomic variables. The two macroeconomic variables are constructed by using the Principal Components Analysis: one macroeconomic variable is based on three time series on real economic activity and the other macroeconomic variable is based on four time series on inflation. Ang and Piazzesi assume orthogonality of the three latent factors and of the two macroeconomic factors. Hence, they explain the short term interest rate by five explanatory variables in an OLS regression. The regression output signalises the dependence of the term structure of interest rates on macroeconomic variables. A Maximum Likelihood estimation of a VAR model of the yield curve including latent factors and macroeconomic factors also supports the hypothesis of the influence of the macroeconomy on the term structure of interest rates. As the central bank responds to macroeconomic shocks by adjusting the short term target rate, up to 85% of the dynamics in the short and middle part of the yield curve can be explained by macroeconomic factors.

Ang, Dong and Piazzesi (2004) state the similarity between a Taylor rule of monetary policy and an affine term structure model, in which the state vector consists of observable macroeconomic factors and one latent factor. In both approaches, the short term interest rate is explained by output and inflation. They construct a no-arbitrage model of the term structure of interest rates which includes a forward- or backward-looking Taylor rule to explain the short term interest rate.[2] The residual of the model, the monetary policy shock, is identified as the scaled latent factor in an affine term structure model. Furthermore, they model time varying risk premia for the macroeconomic variables and therefore do not follow the Pure Expectations Hypothesis which assumes a constant premium. The estimation results of their model show that more than 60% of the variation in yields can be explained by GDP and inflation, whereas the latter is the main determinant of the spread between the short and long term interest rate.

Diebold and Li (2005) focus on out-of-sample forecasting of the term structure of interest rates. They estimate the whole term structure by a Nelson-Siegel (1987) model with three latent factors (level, slope and curvature). Assuming an AR(1) process for the latent factors and allowing for arbitrage, this "sophisticatedly simple" model is able to capture the stylised facts about the term structure of interest rates and to generate good out-of-sample forecasts. One month ahead, the model forecast errors are similar to those of a random walk process. As the level of interest rates tends to be integrated of order

[2] Ang, Dong and Piazzesi (2004) explicitly model the coefficients in the observation equation of a state space system in a model of the term structure of interest rates.

one (I(1)), a random walk process is appropriate to forecast the level of interest rates in the next period. In contrast to that, one year ahead, the forecast error is remarkably lower in the Nelson-Siegel framework than with a random walk process or alternative well specified models.

Diebold, Rudebusch and Aruoba (2005) research on the bidirectional effects between the yield curve and the macroeconomy. They compare their Macro-Finance model with a "yields-only-model" and with a "macro-only-model", whereas the latter is based on the Expectations Hypothesis of the term structure of interest rates. The macroeconomy has a larger effect on the yield curve than the yield curve on the macroeconomy. Nevertheless, they state the important role of bidirectional effects between the term structure of interest rates and the macroeconomy and that both directions of possible impacts should be part of further research.

There is additional research on the feedback effects between the term structure of interest rates and the macroeconomy. The linkage between monetary policy as a macroeconomic variable and the term structure of interest rates is analysed by Piazzesi (2005) and by Kozicki and Tinsley (2001). More articles which research on Macro-Finance models of the term structure of interest rates are Wu (2002), Dewachter and Lyrio (2004), Duffee (2004) as well as Evans and Marshall (2001). Additional research on related aspects are Bernanke, Boivin and Eliasz (2005), Bekaert, Cho and Moreno (2005) and Dai and Philippon (2004), whereas the latter focuses on fiscal shocks on interest rates by using a term structure model. Furthermore, there is a large amount of research on the forecasting ability of the term structure of interest rates concerning the future path of real economic activity, inflation or stock returns (section 4.2.1). If the yield curve is a predictor for inflation, it should be considered as an information variable for the central bank.

In this chapter, section 2.2 discusses the no-arbitrage condition in Macro-Finance models and section 2.3 the Principal Components Analysis of the term structure of interest rates. Section 2.4 presents a two-factor Macro-Finance model of the term structure of interest rates. The interest rate data and macroeconomic data which is used to estimate the empirical macroeconomic model of the yield curve is described in section 2.5. Afterwards, section 2.6 presents the estimation results of the empirical two-factor macroeconomic model of the term structure of interest rates and section 2.7 concludes.

2.2 No-Arbitrage Condition

Macro-Finance models of the term structure of interest rates can be based on relative or absolute asset pricing (section 1.4). Macro-Finance models which are based on relative asset pricing use the no-arbitrage condition. The no-arbitrage condition is equivalent to the absence of a trading strategy with a net capital investment of zero that has a positive and risk-free return. Often, the no-arbitrage condition is implemented in a term structure model that is based on the Stochastic Discount Factor (section 1.3.4). The reason is that today's interest rate of a one-period bond is equal to the expected value of the discount factor in the next period (Cochrane (2001)).

The following presentation of a term structure model using the Stochastic Discount Factor is based on Lemke (2005). The no-arbitrage condition is implemented by a strictly positive Stochastic Discount Factor. The no-arbitrage condition relates the price of a zero-coupon bond which pays one monetary unit at maturity with a time to maturity of $n+1$ at time t (P_t^{n+1}) to the expectations at time t of the product of the Stochastic Discount Factor at time $t+1$ (M_{t+1}) and the price of a zero-coupon bond with a time to maturity of n at time $t+1$ (P_{t+1}^n),[3]

$$P_t^{n+1} = E_t[M_{t+1}P_{t+1}^n]. \tag{2.1}$$

Accordingly, if $n=0$, the price of a zero-coupon bond at time t with a time to maturity of 1 is $P_t^1 = E_t(M_{t+1})$, because at time $t+1$ the price of the zero-coupon bond P_{t+1}^0 with a time to maturity of 0 is equal to 1 ($P_{t+1}^0 = 1$). Applying these steps to a further period and using the law of iterated expectations results in $P_t^2 = E_t(M_{t+1}M_{t+2})$. In general, the price of an n-period zero-coupon bond P_t^n at time t can be defined in terms of the expected Stochastic Discount Factors $(M_{t+1}, ..., M_{t+n})$:

$$P_t^n = E_t(M_{t+1}M_{t+2}...M_{t+n}). \tag{2.2}$$

[3]In an arbitrage-free financial market, the return R_t^i of asset i at time t ($R_t^i = P_t^i/P_{t-1}^i$) has to fulfil the condition: $E_{t-1}(M_tR_t^i) = 1$ (Lemke (2005)).

Defining a stochastic process of the Stochastic Discount Factor that is constrained to the condition that $M_t > 0, \forall\, t$ implements the no-arbitrage condition and constitutes a model of the term structure of interest rates.[4] The conditional expectation of equation 2.2 is the corresponding price (yield) of a bond with a time to maturity of n.

Deutsche Bundesbank (2006) gives a detailed description of a Macro-Finance model of the yield curve with a no-arbitrage condition which is implemented by modelling a strictly positive Stochastic Discount Factor. To guarantee that the Stochastic Discount Factor M_{t+1} is strictly positive, it is modelled by an exponential function that depends on the vector of the explanatory variable(s) X_t, the vector of market prices of risk λ_t and an error term ε_{t+1}:

$$M_{t+1} = \exp(-\frac{1}{2}\lambda_t{}'\lambda_t - a - b'X_t - \lambda_t{}'\varepsilon_{t+1}). \tag{2.3}$$

Equation 2.3 can be used with a one-factor model, i.e. X_t consists only of the short term interest rate, which is modelled by an autoregressive process and a parameter K:

$$X_t = K \cdot X_{t-1} + \varepsilon_t. \tag{2.4}$$

Hence, in a one-factor model, the short term interest rate explains the whole yield curve and the only source of risk is that the expected short term interest rate deviates from the actual short term interest rate. In general, the market price of risk λ_t determines the level of the risk premium and the no-arbitrage condition determines the cross-sectional structure of the risk premium. Empirically, the short term interest rate is not able to explain the whole yield curve, so that additional observable or unobservable variables should be included in X_t. The number of sources of risk is equal to the number of variables included in X_t. The prices of risk λ_t are time varying and depend on X_t,

$$\lambda_t = d + D \cdot X_t, \tag{2.5}$$

where d and D are parameters. If a macroeconomic variable e is included in X_t, λ_e

[4] Lemke (2005) discusses the equivalence of the implementation of the no-arbitrage condition and a strictly positive Stochastic Discount Factor.

(as an element of λ_t) measures the dependence of the yields with different maturities on the economic risk e. However, when the term structure of interest rates is modelled by the Stochastic Discount Factor, the reaction of yields with different maturities to a change of the macroeconomic variable e is restricted by the cross-sectional no-arbitrage condition.

When the no-arbitrage condition is implemented by a strictly positive Stochastic Discount Factor, the framework above can be transformed to an affine model of the term structure of interest rates, where the yield y_{tn} of a bond with a time to maturity n at time t is an affine function of X_t which includes information about the macroeconomy (Ang and Piazzesi (2003)),

$$y_{tn} = A_n + B_n{}'X_t. \tag{2.6}$$

The functional form of the parameters A_n and B_n depends on the no-arbitrage condition and their values depend on the parameters of risk d and D. Similar to the model of the term structure of interest rates based on the Stochastic Discount Factor, all estimated parameters are restricted by the cross-sectional no-arbitrage condition in the affine model. Hence, the impact of the macroeconomic variables on yields with different maturities is determined by the cross-sectional no-arbitrage condition.

Nevertheless, some models of the term structure of interest rates which include macroeconomic variables neglect the no-arbitrage condition. For example, Diebold, Rudebusch and Aruoba (2005) model the term structure of interest rates based on latent factors and observable macroeconomic variables without the no-arbitrage condition. They state that the no-arbitrage condition is important to fit the term structure of interest rates at one point in time (cross-sectional perspective). However, a model including the no-arbitrage condition is not able to capture the dynamics of the term structure appropriately (time series perspective). As the focus of the macroeconomic term structure model in section 2.4 has a medium term perspective, the time series behaviour of the interest rates and macroeconomic variables is important. As a consequence, the empirical macroeconomic model of the term structure of interest rates in this analysis neglects the no-arbitrage condition.

	Yields in Levels		Yields in First Differences	
n	Proportion of Total Variance Explained by n-th Principal Component	Total Variance Explained by First n Principal Components	Proportion of Total Variance Explained by n-th Principal Component	Total Variance Explained by First n Principal Components
1	0.937	0.937	0.713	0.713
2	0.056	0.993	0.188	0.901
3	0.005	0.999	0.040	0.941
4	0.001	0.999	0.033	0.974
5	0.000	1.000	0.016	0.991

Table 2.1: Proportion of the variance of the German yield curve (levels and first differences) explained by Principal Components.

2.3 Principal Components Analysis

In the literature on the term structure of interest rates, the Principal Components Analysis has been widely used since the influential paper by Litterman and Scheinkman (1991). In an analysis of hedging bond portfolios, Litterman and Scheinkman state that three factors are able to explain almost all variation of yields of zero-coupon bonds. These three factors are named level, slope (or steepness) and curvature. In their empirical analysis, a change of the level factor has the same effect on yields of all maturities. The slope factor has a strong negative correlation with the short term interest rate which decreases in absolute terms to zero for interest rates with a time to maturity of five years. For maturities from five to 18 years, the correlation is positive and increases, whereas afterwards the correlation slowly declines. The curvature factor leads to a more pronounced curvature of the shape of the yield curve between the short term interest rate and a maturity of twenty years. Litterman and Scheinkman find that the first three Principal Components of zero-coupon yields in the United States explain 98.4% of the variance in the yield curve.[5]

These results are very similar to those of zero-coupon yields in Germany, which are used for the empirical macroeconomic model of the term structure of interest rates in section 2.4. The Principal Components Analysis of the data of the German term structure of interest rates, which is described in section 2.5, shows that the first three

[5]Diebold and Li (2005) also state that the first three factors can explain up to 99% of the variation of yields.

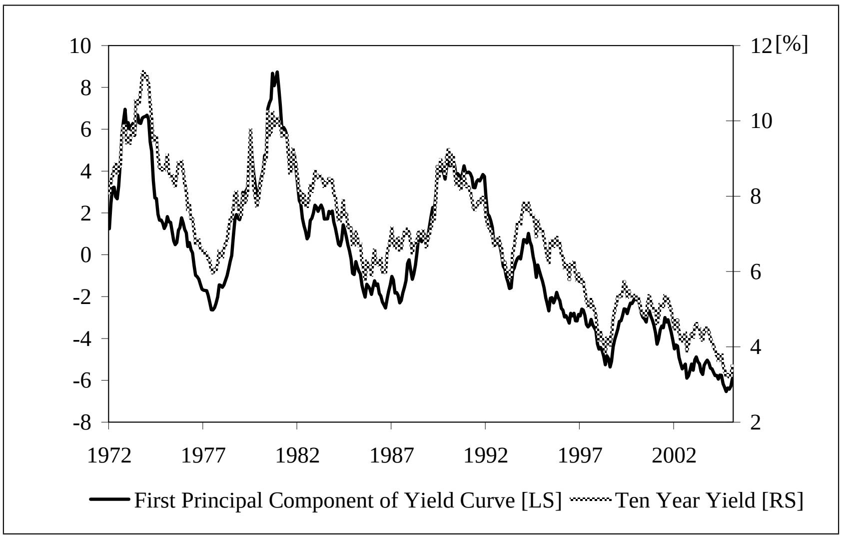

Figure 2.1: First Principal Component of the yield curve and ten-year interest rate.

Principal Components are able to explain 99.9% of the variation of 13 zero-coupon yields (table 2.1).

Diebold, Piazzesi and Rudebusch (2005) research on the empirical counterpart of the first three Principal Components of the yield curve. The First Principal Component (level factor) is empirically represented by the long term interest rate, the Second Principal Component (slope factor) is empirically represented by the spread between the long and short term interest rate and the Third Principal Component (curvature factor) is empirically represented by the medium term interest rate minus the sum of the short and the long term interest rate.[6]

The correlation of the first two Principal Components of the German yield curve with their empirical counterparts between September 1972 and October 2005 is strong (figures 2.1 and 2.2). The correlation of the ten-year long term interest rate and the First Principal Component is 0.957 and of the slope of the yield curve (ten-year interest rate minus three-month interest rate) and the Second Principal Component is 0.843.[7]

Diebold and Li (2005) interpret the parsimonious and parametric approach to model the yield curve by Nelson and Siegel (1987) as a three-factor model of the term structure of interest rates. They relate the three parameters of the Nelson and Siegel model to the

[6]The exact specification of the short, medium and long term interest rate varies in the literature.

[7]The correlations are calculated by the data plotted in figures 2.1 and 2.2.

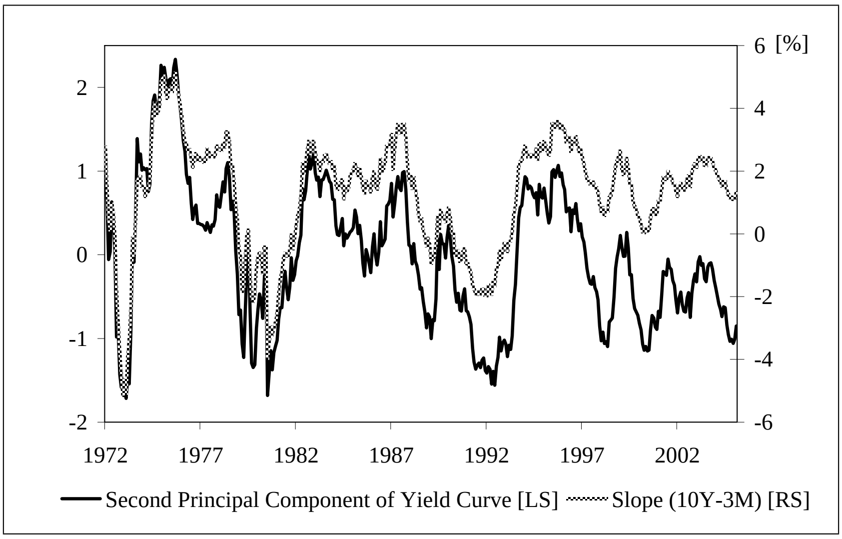

Figure 2.2: Second Principal Component and slope (10Y-3M) of the yield curve.

first three Principal Components. In the Nelson and Siegel model, a single interest rate is modelled by three parameters which represent the first three Principal Components of the yield curve (three latent factors) and a fourth parameter.[8] The loadings of the three latent factors depend on the maturity of the interest rate which is explained and on the fourth parameter. As the Nelson and Siegel model of the term structure of interest rates cannot explain the yield curve perfectly at one point in time (cross-sectional perspective), it is not used to price bonds or derivatives in Finance. In contrast to that, the Nelson and Siegel model is used in Macroeconomics, for example by central banks, because it has a good ability to explain the overall shape of the yield curve.

2.4 A Two-Factor Macro-Finance Model

In this section, an empirical two-factor macroeconomic model of the yield curve is presented. The model focuses on the macroeconomic determinants of the yield curve in the medium term.[9] The yield curve is explained by the first two Principal Components, whereas the empirical counterparts of these two factors are modelled by macroeconomic

[8] The fourth parameter influences the shape of the yield curve, i.e. it determines the maturity spectrum of the local maximum or minimum.

[9] The focus of this model is different from models of the term structure of interest rates in Finance that fit the observed term structure of interest rates as perfectly as possible in a cross-sectional perspective.

theory. This contrasts with some yield curve models which are used in Finance, where the dynamics of the factors are purely determined by a stochastic process (section 1.4).

In this empirical macroeconomic model, the yield curve is only explained by two factors, as two factors are sufficient to model the yield curve (section 2.3). The two factors that explain the yield curve (level and slope) are latent. So, their empirical counterparts are modelled by this empirical macroeconomic model. The empirical counterpart of the First Principal Component (level factor) is the long term interest rate and the empirical counterpart of the Second Principal Component (slope factor) is the interest rate spread between the long and the short term interest rate. Accordingly, the ten-year interest rate of a government bond and the spread between the ten-year interest rate and the three-month money market interest rate are modelled.

This empirical macroeconomic model is similar to affine models of the term structure of interest rates, where the process of the state vector is governed by the state equation and the observation equation relates the observed yields to the state vector (section 1.4). Analogous, this empirical macroeconomic model consists of two steps to explain the term structure of interest rates. In one step (section 2.4.1), the interest rate of a certain time to maturity is explained by the empirical counterparts of the First and Second Principal Component and their weights (factor loadings) are estimated. In another step (sections 2.4.2 and 2.4.3), two equations are used to explain the empirical counterparts of the First and Second Principal Component by economic theory. Figure 2.3 shows the framework of the empirical two-factor Macro-Finance model of the term structure of interest rates.

2.4.1 Modelling the Factor Loadings

Each point of the yield curve can be explained by the first two Principal Components of the whole yield curve (section 2.3). The factor loadings of the level and slope factor are empirically determined by their past influence on the interest rate of a certain time to maturity. In contrast to the two empirical counterparts of the level and slope factors which are modelled by macroeconomic theory, the factor loadings of these factors on an interest rate with a certain maturity are only determined by a regression based on

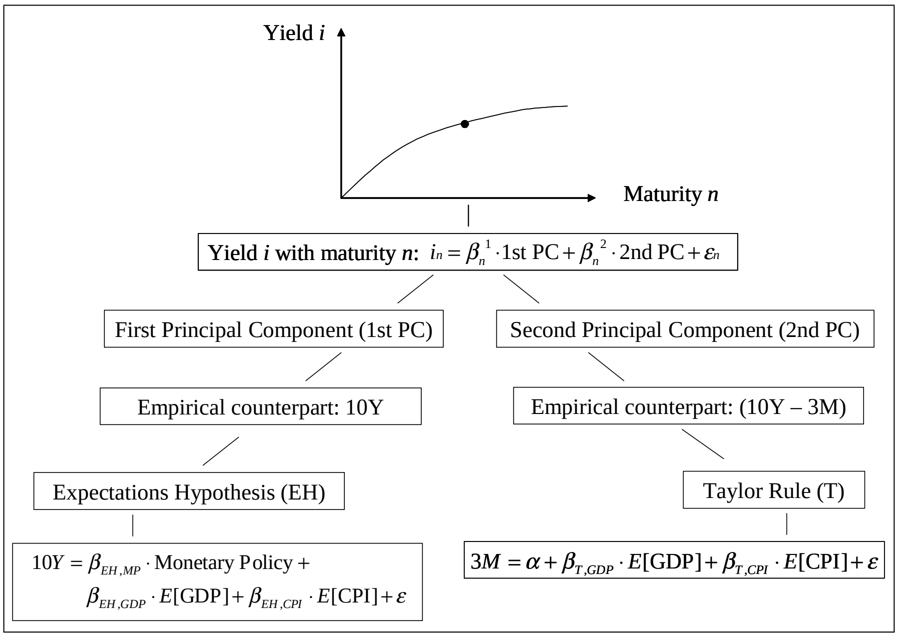

Figure 2.3: Framework of the empirical two-factor Macro-Finance model of the term structure of interest rates.

historical data:

$$i_n = \beta_n^1 \cdot \text{1st PC} + \beta_n^2 \cdot \text{2nd PC} + \varepsilon_n, \tag{2.7}$$

whereas β_1^n and β_2^n are the factor loadings of the First and Second Principal Component for the interest rate i_n with maturity n and ε_n is the error term. Using the empirical counterparts of the Principal Components (ten-year interest rate $(10Y)$ for the First Principal Component and the spread between the ten-year and three-month interest rate $(10Y - 3M)$ for the Second Principal Component) in equation 2.7 results in,[10]

$$i_n = \beta_n^1 \cdot (10Y) + \beta_n^2 \cdot (10Y - 3M) + \varepsilon_n. \tag{2.8}$$

2.4.2 Modelling the Level Factor

The level factor, i.e. the interest rate of a ten-year government bond, is explained by the Expectations Hypothesis (section 1.3.3). The Expectations Hypothesis defines the long term interest rate as the expected average of future short term interest rates plus the corresponding premium (equation 1.3). In order to explain the long term interest

[10] The estimation results of equation 2.8 are presented in section 2.6.1.

rate with macroeconomic variables, it is assumed that GDP and CPI affect both the expected future average of the short term interest rate and the premium.[11]

Current and expected GDP and CPI have an impact on the average of future short term interest rates, because GDP and CPI are two of the most important information variables for a central bank when deciding on the target rate. Consequently, the future path of the short term interest rate and its expected average are determined by GDP and CPI (GDP and CPI are the input variables in a Taylor rule of monetary policy (section 2.4.3)). In addition to that, past, current and expected values and volatilities of GDP and CPI determine the risk aversion of investors. This affects the risk premium that investors demand in order to be compensated for holding a long term bond.

According to the Expectations Hypothesis, the determinants of an h-year interest rate at time t are the expected average of short term interest rates over the next h years $E_t[\varnothing 3M_{t,t+h}]$ and the premium b_t at time t, which may be positive, zero or negative depending on risk aversion and preferred habitat. In this analysis, the forecast horizon h is ten years, because the ten-year interest rate ($10Y_t$) at time t is modelled:

$$10Y_t = E_t[\varnothing 3M_{t,t+h}] + b_t. \tag{2.9}$$

In the following equations 2.10 and 2.11, both components of equation 2.9 are separately related to the expectations of the macroeconomic variables GDP and CPI. A forward-looking Taylor rule of monetary policy explains the average of future expected short term interest rates ($E_t[\varnothing 3M_{t,t+h}]$) by current and expected values of GDP and CPI:

$$E_t[\varnothing 3M_{t,t+h}] = f(E_t[GDP_{t,t+h}], E_t[CPI_{t,t+h}]). \tag{2.10}$$

Furthermore, the premium b_t also depends on macroeconomic variables, because it reflects the expectations of the investors on the future path of the macroeconomy, which is represented by the expectations of GDP and CPI:

$$b_t = f(E_t[GDP_{t,t+h}], E_t[CPI_{t,t+h}]). \tag{2.11}$$

[11]The relationship between the macroeconomy and the long term interest rate is discussed in section 1.2.

Equations 2.9, 2.10 and 2.11 can be combined to formulate the relationship between the ten-year interest rate and GDP (equation 2.12) and between the ten-year interest rate and CPI (equation 2.13):

$$\frac{\delta(10Y_t)}{\delta E_t[GDP_{t,t+h}]} = \underbrace{\frac{\delta(10Y_t)}{\delta E_t[\varnothing 3M_{t,t+h}]} \cdot \frac{\delta E_t[\varnothing 3M_{t,t+h}]}{\delta E_t[GDP_{t,t+h}]}}_{\substack{\text{Effect of expected GDP} \\ \text{on the long term interest rate} \\ \text{via the short term interest rate}}} + \underbrace{\frac{\delta(10Y_t)}{\delta b_t} \cdot \frac{\delta b_t}{\delta E_t[GDP_{t,t+h}]}}_{\substack{\text{Effect of expected GDP} \\ \text{on the long term interest rate} \\ \text{via the premium}}}, \tag{2.12}$$

$$\frac{\delta(10Y_t)}{\delta E_t[CPI_{t,t+h}]} = \underbrace{\frac{\delta(10Y_t)}{\delta E_t[\varnothing 3M_{t,t+h}]} \cdot \frac{\delta E_t[\varnothing 3M_{t,t+h}]}{\delta E_t[CPI_{t,t+h}]}}_{\substack{\text{Effect of expected CPI} \\ \text{on the long term interest rate} \\ \text{via the short term interest rate}}} + \underbrace{\frac{\delta(10Y_t)}{\delta b_t} \cdot \frac{\delta b_t}{\delta E_t[CPI_{t,t+h}]}}_{\substack{\text{Effect of expected CPI} \\ \text{on the long term interest rate} \\ \text{via the premium}}}. \tag{2.13}$$

In equation 2.12, the expectations of GDP growth influence the long term interest rate via the short term interest rate and via the premium. The net effect should be positive, as the effect via the short term interest rate is positive, because a higher demand for capital directly increases the long term interest rate, as a higher supply of bonds results in lower bond prices. This effect has a larger magnitude than the effect via the premium. The effect of GDP on the long term interest rate via the premium should be mainly driven by the volatility of GDP, whereas a higher volatility of GDP increases the premium. However, equation 2.12 only includes expectations of the mean of GDP and not of its volatility.[12]

The expectations of CPI also influence the long term interest rate via the short term interest rate and via the premium (equation 2.13). Similar to equation 2.12, the net effect should be positive due to the large positive effect of the level of CPI on the short term interest rate. The reason is that the central bank raises the short term interest rate as a reaction to an increase in the price level. Again, the effect via the premium should be mainly driven by the volatility of CPI, whereas a higher volatility of CPI increases the premium.

Another interpretation of equations 2.12 and 2.13 can be made in line with Wu (2006), who decomposes the nominal long term interest rate (based on the Fisher Identity

[12] The effects of the realized macroeconomic volatility on the linkages between the macroeconomy and the term structure of interest rates are empirically analyzed in sections 2.6.2 and 2.6.3.

(section 1.3.2)) into four elements: expected real interest rate, real interest rate risk premium, expected inflation and inflation risk premium.[13] Hence, the effect of expected GDP on the long term interest rate via the short term interest rate can be seen as the effect of expected GDP on the expected real interest rate. Analogous, the effect of expected CPI on the long term interest rate via the short term interest rate can be seen as the effect of expected CPI on expected inflation. The effects of GDP and CPI on the long term interest rate via the premium in equations 2.12 and 2.13 sum up to b_t (equation 2.9). According to Wu, b_t can be seen as the sum of the real interest rate risk premium ($b_{t,\text{real}}$) and the inflation risk premium ($b_{t,\text{inflation}}$), i.e. $b_t = b_{t,\text{real}} + b_{t,\text{inflation}}$. The effect of expected GDP on the long term interest rate via the premium is $b_{t,\text{real}}$ (in equation 2.12, b_t denotes $b_{t,\text{real}}$). Accordingly, the effect of expected CPI on the long term interest rate via the premium is $b_{t,\text{inflation}}$ (in equation 2.13, b_t denotes $b_{t,\text{inflation}}$).

The expected average of future short term interest rates, which is one determinant of the long term interest rate according to the Expectations Hypothesis, is an equally weighted average of future short term interest rates. However, in reality, the investors' expectations of the near future have a higher weight in the average of expected short term interest rates, because of the higher confidence in short term forecasts than in long term forecasts. As a consequence, current GDP and CPI, which determine the expectations of the investor in the short term for GDP and CPI, are used to approximate the investors' long term expectations of GDP and CPI. The long term expectations of GDP and CPI in turn influence the long term expectations of the short term interest rate.[14]

The empirical Macro-Finance model of the term structure of interest rates in this chapter interprets equation 2.9 as a regression equation with $10Y_t$ as the dependent variable, the expected short term interest rate (i.e. $E_t[GDP_{t,t+h}]$ and $E_t[CPI_{t,t+h}]$) as explanatory variables and the term premium b_t as the error term. The expectations of the level of GDP growth and the change of CPI should be nearly uncorrelated with

[13]The Fisher Identity decomposes a nominal interest rate into a real component and into expected inflation. Hence, the nominal long term interest rate is the sum of the real interest rate, i.e. the long term GDP growth (the growth potential of the economy) and the long term expected inflation, i.e. the inflation target of a credible central bank.

[14]In this model, it is assumed that the investor expects the central bank to act according to a Taylor rule.

the premium (the error term), because the premium should mainly be affected by the volatility of changes in GDP and CPI. Therefore, it is assumed that the explanatory variables are uncorrelated with the error term and equation 2.9 is estimated by OLS. Section 2.6 presents the estimation results of this OLS regression and empirically analyses the impact of realized macroeconomic volatility on the effects of GDP and CPI on the long term interest rate.

2.4.3 Modelling the Slope Factor

Similar to the macroeconomic explanation of the level factor in the previous section, the slope factor is explained by macroeconomic theory. As the empirical counterpart of the slope factor is the difference between the long and short term interest rate and the long term interest rate has been modelled in the previous section, the short term interest rate is explained by a Taylor rule of monetary policy in this section.

Taylor (1993) constitutes a monetary policy rule to explain the appropriate target rate of the central bank in line with the state of the macroeconomy. The target rate depends on the growth rate of the economy relative to its potential growth rate as well as on the inflation rate relative to the inflation target of the central bank. Sauer and Sturm (2004) connect the Taylor rule to the ECB's monetary policy and use the following representation of the Taylor rule:

$$i_t = r^* + \pi_t + \gamma_\pi(\pi_t - \pi^*) + \gamma_y(y_t - y^*) + \xi_t, \qquad (2.14)$$

where i_t is the target rate of the central bank at time t, r^* the equilibrium real interest rate, π_t the inflation rate, π^* the inflation target of the central bank, y_t the GDP growth rate of the economy, y^* the potential growth rate of the economy and ξ_t the corresponding error term. The impact of the difference between the inflation rate π_t and the inflation target by the central bank π^* on the target rate of the central bank i_t is quantified by γ_π. Analogous, γ_y measures the impact of the difference between the GDP growth rate y_t and the potential growth rate of the economy y^* on the target rate of the central bank i_t. According to economic theory, the coefficients γ_π and γ_y should be positive: an inflation rate higher than the inflation target of the central bank and a

GDP growth rate higher than the potential growth rate of the economy have a positive impact on the target rate of the central bank. Taylor proposes one half as value for the coefficients of the deviation of the macroeconomic variables relative to their reference values. Alternative formulations of the Taylor rule in equation 2.14 are equations 2.15 and 2.16:[15]

$$i_t = (r^* - \gamma_\pi \pi^*) + (1 + \gamma_\pi)\pi_t + \gamma_y(y_t - y^*) + \xi_t, \tag{2.15}$$

$$i_t = c + \beta_\pi \cdot \pi_t + \beta_y \cdot (y_t - y^*) + \xi_t. \tag{2.16}$$

2.5 Data Description

The data set of interest rates is obtained by the Deutsche Bundesbank.[16] As it is common in empirical studies on the yield curve, the short end is represented by money market interest rates with maturities between one month and six months.[17] The rest of the yield curve is represented by default free zero-coupon government bonds with maturities between one and ten years. The data of the default free zero-coupon government bonds is calculated by the Deutsche Bundesbank according to the parametric Svensson approach with market data for listed Federal coupon-bearing securities without default risk. Due to the parametric approach, the time series of the interest rates have a constant maturity so that the data can be used in an empirical Macro-Finance model of the yield curve.

The data consists of 398 monthly observations between September 1972 and October 2005 of money market and government bond interest rates. The money market interest rates with maturities of one month (1M), three months (3M) and six months (6M) are monthly averages and reported by Frankfurt banks.[18] Most of the term structure of interest rates consists of interest rates of government bonds with maturities between

[15] The estimation results of equation 2.16 are presented in section 2.6.3.

[16] The data can be obtained on the webpage www.bundesbank.de. A description of the construction of the data can be found in Deutsche Bundesbank (2005).

[17] For example, Deutsche Bundesbank (2006) uses money market interest rates with a maturity of six months for the short end of the yield curve.

[18] In the period between September 1972 and March 1981, data for the six-month money market rate is not available. In order to fill the gap for the corresponding period, the missing values are calculated as the mean between the three-month money market rate and the one-year government bond interest rate.

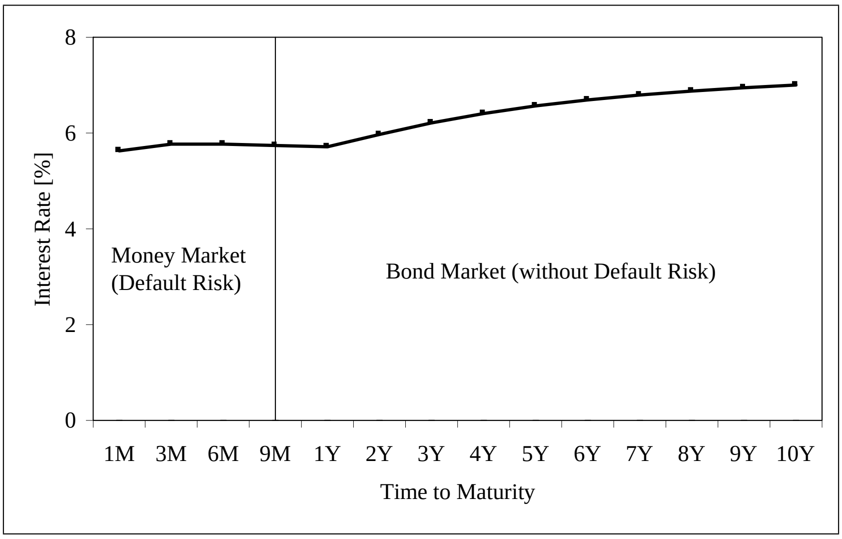

Figure 2.4: Average yield curve in Germany between September 1972 and October 2005, whereas the nine-month interest rate is the average between the six-month money market rate and the one-year government bond rate. Source: Deutsche Bundesbank.

one year (1Y) and ten years (10Y). The interest rates of government bonds are end of month data.

As the data for one, three and six months interest rates is reported by banks in Frankfurt for money transactions, it is not default free, because banks are exposed to default risk. That is the reason why money market interest rates include a default risk premium in contrast to default free zero-coupon yields. This can be seen in figure 2.4, where the mean yield curve of short term maturities has a hump. Consequently, the mean interest rate of a one-year default free zero-coupon bond is lower than the mean money market interest rate for three and six months. The average spread between the interest rate of ten-year government bonds and the three-month money market rate, i.e. the average slope of the yield curve, is 123 basis points. The reason for the positive slope might be that investors expect on average an increase of the short term interest rate and that the risk premium is positive.

In addition to the plot of the historical German yield curve (figure 1.4), table 2.2 summarizes descriptive statistics of the German term structure for both interest rates in levels and in first differences. Interest rates with short term maturities are more volatile than interest rates with long term maturities, which is a typical characteristic of interest rate data in levels. For example, the standard deviation of the level of the three-

	Yields in Levels				Yields in First Differences			
	3M	2Y	5Y	10Y	3M	2Y	5Y	10Y
Mean	5.77	5.97	6.57	7.00	-0.01	-0.01	-0.01	-0.01
Median	4.82	5.64	6.45	6.98	0.00	-0.03	-0.04	-0.03
Maximum	14.57	12.33	11.49	11.30	2.93	1.52	1.25	1.20
Minimum	2.01	2.04	2.56	3.21	-1.42	-1.21	-0.91	-0.84
Standard Deviation	2.86	2.28	2.00	1.75	0.39	0.34	0.27	0.25
Skewness	0.92	0.36	0.07	-0.02	1.57	0.57	0.51	0.64
Kurtosis	3.17	2.33	2.21	2.42	14.23	5.94	4.52	5.04
Autocorrelation	0.989	0.987	0.987	0.984	0.442	0.215	0.214	0.107

Table 2.2: Descriptive statistics of German yields in levels and first differences.

month interest rate of 2.86 is larger than of the ten-year interest rate of 1.75, because the central bank reacts to the business cycle by changing the short term interest rate, which only has a smaller effect on long term interest rates. Skewness and kurtosis of the level of German interest rates indicate that the various interest rates are not normally distributed, as the Gaussian distribution has a skewness equal to zero and a kurtosis equal to three.

The first difference of the interest rates shows the typical non-normal distribution of changes in financial market data: the skewness is positive and indicates that a decrease in the interest rate is more likely than an increase, which is in line with the decline in the level of interest rates in Germany during the sample (figure 1.4). The kurtosis is larger than three and indicates that the probability distribution of the first differences has thicker tails than the normal distribution. The autocorrelation of the time series of the level of the interest rates is very high. Therefore, next period's value of a certain interest rate heavily depends on the value of the interest rate in the period before.

The correlation between interest rates in levels and the correlation between interest rates in first differences is also high. In figure 2.5, the correlation of yields in levels is close to one for yields with similar time to maturities. The larger the difference in the time to maturity of two yields, the lower the correlation between them. In figure 2.6, the correlation between the first difference of two yields with different maturities n and m ($Corr(i_t^n - i_{t-1}^n, i_t^m - i_{t-1}^m)$) is plotted. At the short end of the yield curve, the correlation between yields in first differences is not as large as between yields in levels, because the correlation between yields in first differences declines faster as the difference in the time

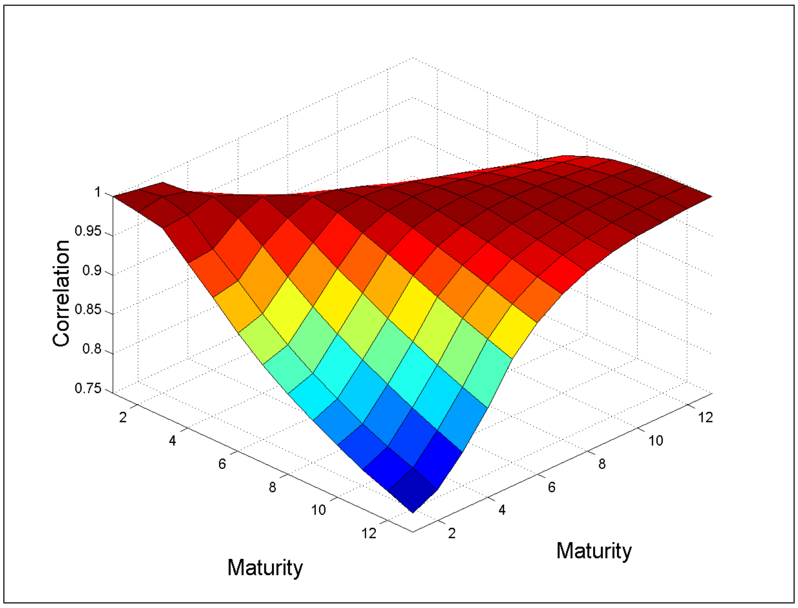

Figure 2.5: Correlation of German interest rates in levels.

to maturity of two yields widens. Interest rates with medium and long term maturities have similar correlations in first differences as in levels.[19]

The macroeconomic data set consists of time series for real economic activity and for inflation. Even though real GDP growth is the best information variable for the real economy, the business sentiment indicator Ifo-Index is used as an approximation for GDP in this analysis. The Ifo-Index is published monthly and therefore has a larger number of observations than GDP, which is only published quarterly. Furthermore, the Ifo-Index is a leading indicator for the real economy and therefore it is possible to include expectations of the future path of the real economy into this empirical macroeconomic model of the yield curve. The time series of the Ifo-Index is seasonally adjusted and the source is the Ifo institute. The development of prices in the economy is represented by the CPI. The data considers wholesale and retail sales and does not take into account energy prices, which is useful as central banks and long term investors do not react to short term fluctuations in prices due to volatile energy prices. The data is also seasonally adjusted and the source is the Deutsche Bundesbank.

[19]The correlation of yields in levels and in first differences is also shown in appendix A.2.

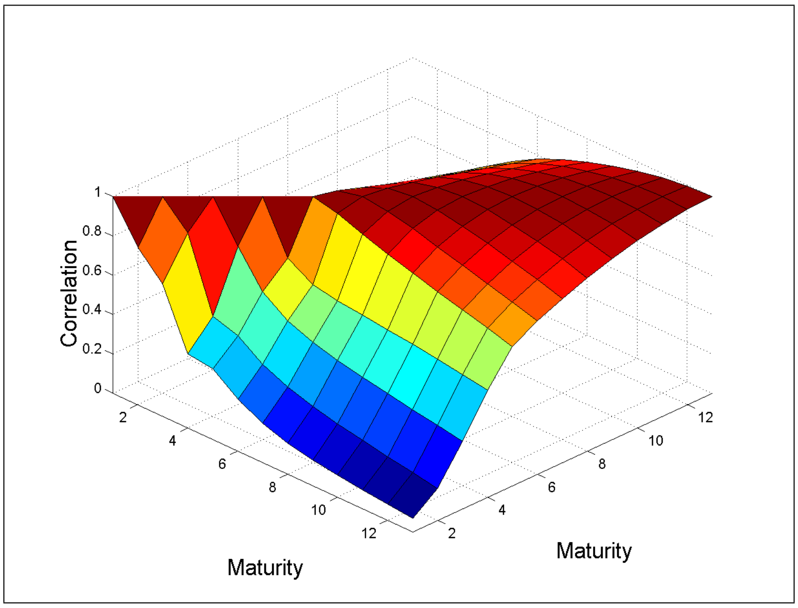

Figure 2.6: Correlation of German interest rates in first differences.

2.6 Estimation Results

This section presents the estimation results of the empirical two-factor Macro-Finance model of the term structure of interest rates discussed in section 2.4. The sample of the time series data for the interest rates in Germany is July 1978 to October 2005. Even though this sample period contains the German Reunification and the change from the Deutsche Bundesbank to the European Central Bank, the estimation results confirm significant effects of the real economy on the term structure of interest rates.

In section 2.6.1, the factor loadings of the empirical counterparts of the First (level factor) and Second Principal Component (slope factor) on an interest rate with a certain time to maturity are empirically determined. In sections 2.6.2 and 2.6.3, the estimation results according to the Expectations Hypothesis and the Taylor rule are presented. In both sections, the effect of realized macroeconomic volatility on the relationship between the real economy and the yield curve is empirically analysed. Section 2.6.4 summarises.

2.6.1 Estimation of the Factor Loadings

According to equation 2.8, the factor loadings (coefficients) are estimated by an OLS regression over the sample September 1972 to October 2005 (398 monthly observations).

Interest Rate with Maturity n	1st PC 10Y	2nd PC (10Y-3M)	R^2	Sum of Squ. Residuals	Akaike Info Criterion	Durbin-Watson
6m	0.97	-0.87	0.99	35.24	0.42	0.30
1y	0.94	-0.68	0.95	115.02	1.61	0.36
2y	0.95	-0.51	0.95	104.43	1.51	0.21
3y	0.96	-0.38	0.95	86.89	1.33	0.18
4y	0.97	-0.28	0.96	63.66	1.02	0.17
5y	0.97	-0.21	0.97	42.37	0.61	0.16
6y	0.99	-0.15	0.98	25.64	0.11	0.17
7y	0.99	-0.10	0.99	13.51	-0.54	0.18
8y	0.99	-0.06	0.996	5.66	-1.41	0.20
9y	0.998	-0.03	0.999	1.34	-2.85	0.22

Table 2.3: Estimation of the coefficients of the First and Second Principal Component.

Table 2.3 presents the estimation results of the factor loadings of the level and slope factor on interest rates with a maturity n of six months and from one to nine years.

Besides, moving window OLS regressions based on 60 monthly observations are used to estimate the coefficients over time. The time series of the coefficients of the level and slope factor for maturities of six months and two, five and nine years are plotted in figures 2.7 to 2.10. The factor loading of the First Principal Component is around 1 for all maturities, whereas the variation of the factor loading of the First Principal Component is the smallest for long term maturities. The factor loading of the Second Principal Component depends on the maturity of the interest rate. At the short end of the yield curve, the factor loading of the Second Principal Component is around -1 and decreases in absolute terms as the maturity of the interest rate increases. At the long end of the yield curve, the factor loading of the Second Principal Component is around 0.[20] In general, the magnitude of the variation in the coefficients for the level factor is smaller than in the coefficients for the slope factor.[21]

[20] The increase of the factor loading of the Second Principal Component as the time to maturity increases is plotted in appendix A.3.

[21] The time series of the weights of the empirical counterparts of the First and Second Principal Component of maturities between six months and nine years can be found in appendix A.3.

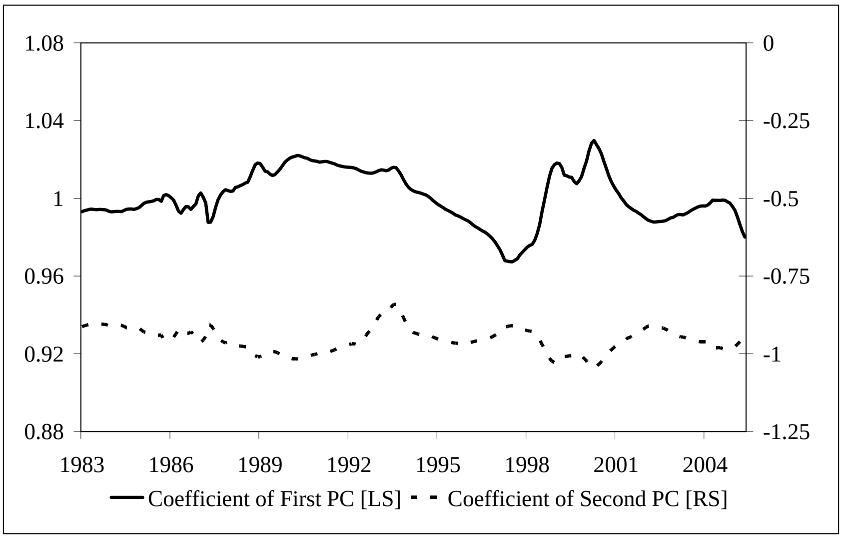

Figure 2.7: Time series of factor loadings of the First and Second Principal Component explaining the six-month interest rate.

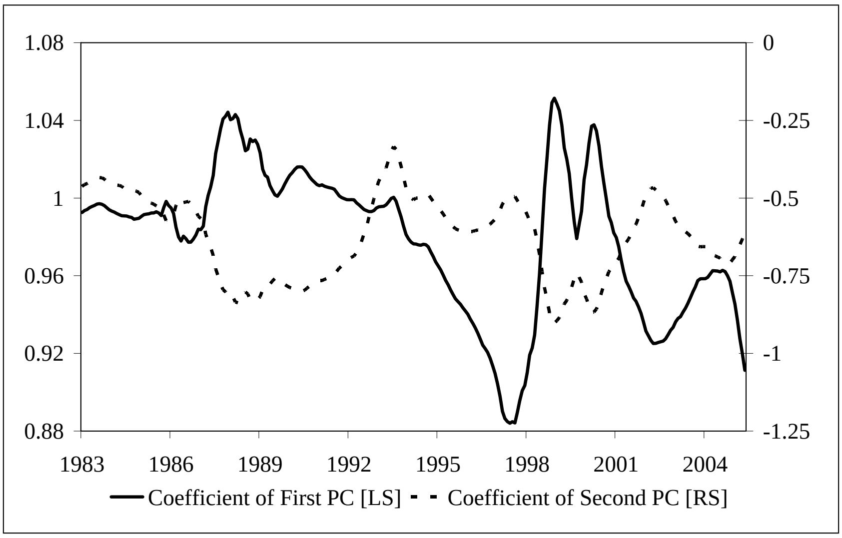

Figure 2.8: Time series of factor loadings of the First and Second Principal Component explaining the two-year interest rate.

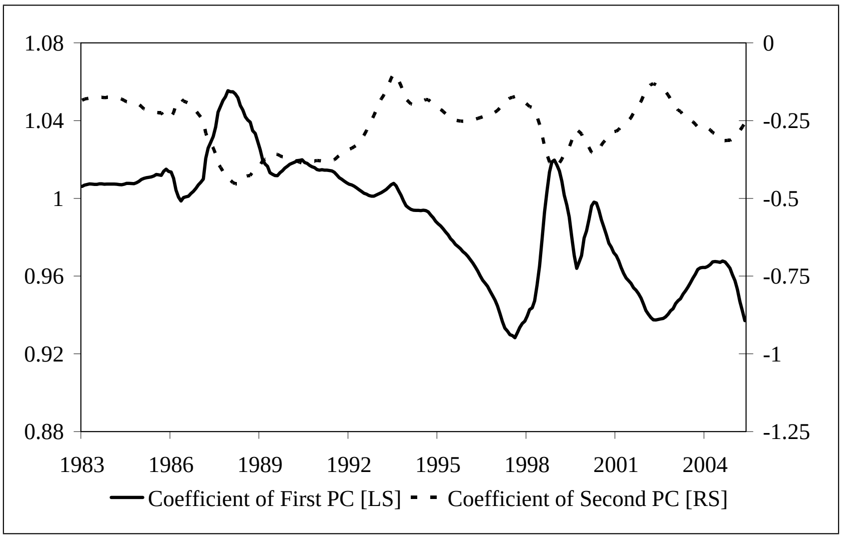

Figure 2.9: Time series of factor loadings of the First and Second Principal Component explaining the five-year interest rate.

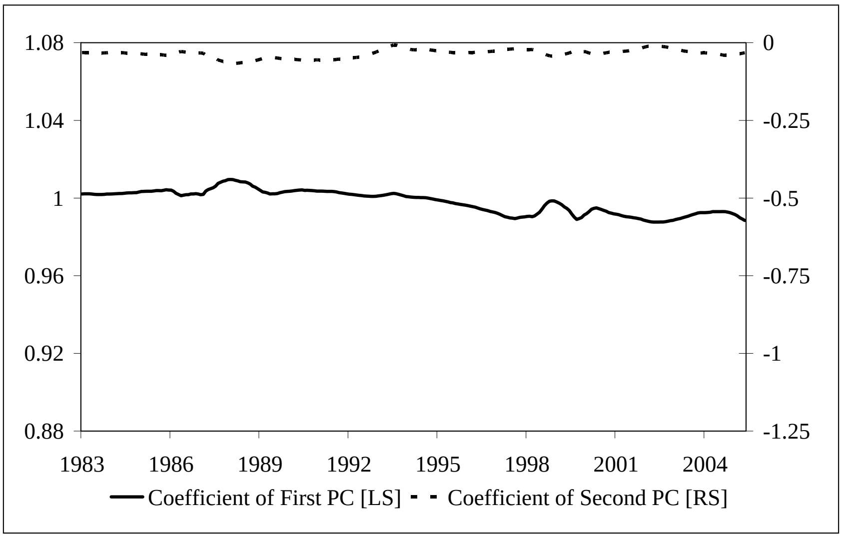

Figure 2.10: Time series of factor loadings of the First and Second Principal Component explaining the nine-year interest rate.

2.6.2 Estimation of the Level Factor

The level factor is explained according to equation 2.9 by the Expectations Hypothesis. Accordingly, the long term interest rate depends on the expected average of short term interest rates which in turn depend on the expectations of GDP and CPI. In addition to that, the current short term interest rate is included as an explanatory variable, because it also significantly determines the expectations of short term interest rates.[22] Equation 2.17 explains the long term interest rate by monetary policy, real economic activity and inflation, whereas all explanatory variables approximate the expectations of market participants for the explanatory variables. An OLS regression with 328 monthly observations between July 1978 and October 2005 leads to the following results (t-values in parenthesis):

$$\begin{aligned} 10Y_t &= \underset{(34.04)}{3.54} + \underset{(17.07)}{0.44} \cdot 3M_t + \underset{(9.49)}{6.74} \cdot Ifo_t + \underset{(5.36)}{0.27} \cdot CPI_t, \\ \overline{R}^2 &= 0.77,\ \mathrm{DW} = 0.14,\ \mathrm{obs.} = 328, \end{aligned} \tag{2.17}$$

where $3M_t$ is the three-month money market rate at time t and Ifo_t is the deviation of the level of the Ifo-Index from its 60-month moving average,

$$Ifo_t = \frac{Ifo\ level_t - [60\text{-}month\ moving\ average\ (Ifo\ level)]_t}{[60\text{-}month\ moving\ average\ (Ifo\ level)]_t}. \tag{2.18}$$

The variable Ifo_t indicates the state of the real economy and is an approximation of the output gap (section 4.3.2). CPI_t is the yearly percentage change of consumer prices in Germany, whereas energy prices are excluded from the price index. The regression has a high adjusted $\overline{R}^2$ of 0.77 and the constant as well as all coefficients have significant t-values.

The Durbin-Watson statistic (DW) of 0.14 indicates a significant positive autocorrelation. A possible reason for the positive autocorrelation might be that the regression is a spurious regression. However, because of the macroeconomic theory behind equation

[22] The inclusion of the short term interest rate in the empirical analysis is due to preliminary research and to the fact that the expectations of financial market participants of future short term interest rates are strongly influenced by the current short term interest rate.

2.17, the relationship between the long term interest rate and macroeconomic variables is not a spurious regression. Another reason for the positive autocorrelation might be the high persistence of interest rates (table 2.2). Therefore, the inclusion of an autoregressive dependent variable would increase the fit of the model. Nevertheless, this two-factor Macro-Finance model of the yield curve neglects autoregressive dependent variables, because this chapter focuses on the macroeconomic determinants of the yield curve.

Another reason for the positive autocorrelation might be a misspecification, i.e. not all relevant information is included in the regression. A misspecification of equation 2.17 could be signalled by a Cusum of squares test of the recursive residuals. The test result (appendix A.4) indicates that the estimated parameters are not stable over the sample. During most of the periods, the test statistic is outside the confidence interval and signals instable parameters. Therefore, the effects of the macroeconomic variables on the long term interest rate depend on additional factors which are not included in the estimation equation.

To research on the time-varying effect of monetary policy and the macroeconomy on the long term interest rate, equation 2.17 is estimated by a moving window OLS regression based on subsamples of 60 months. The t-values of the coefficients of the various regressions are plotted in figure 2.11 for the time period July 1983 and October 2005. The first subsample covers the period between August 1978 and July 1983. Moving forward the subsample by one month leads to 268 observations, whereas the most recent subsample ends in October 2005. The t-values capture the size of the impact and its statistical significance, because the standard deviation of the estimated coefficient is taken into account (Entorf (1998)).

The t-values in figure 2.11 vary significantly over time. A reason for this might be the time-varying realized volatility of the macroeconomy. Rudebusch, Swanson and Wu (2006) state that macroeconomic volatility has an impact on the long term interest rate.[23] Consequently, realized macroeconomic volatility should affect the impact of

[23]According to Rudebusch, Swanson and Wu (2006), the reduced macroeconomic volatility and the reduced uncertainty of monetary policy are important reasons for the low level of long term interest rates in the US despite several increases of the Fed Funds target rate during the period of Greenspan's conundrum (section 1.2).

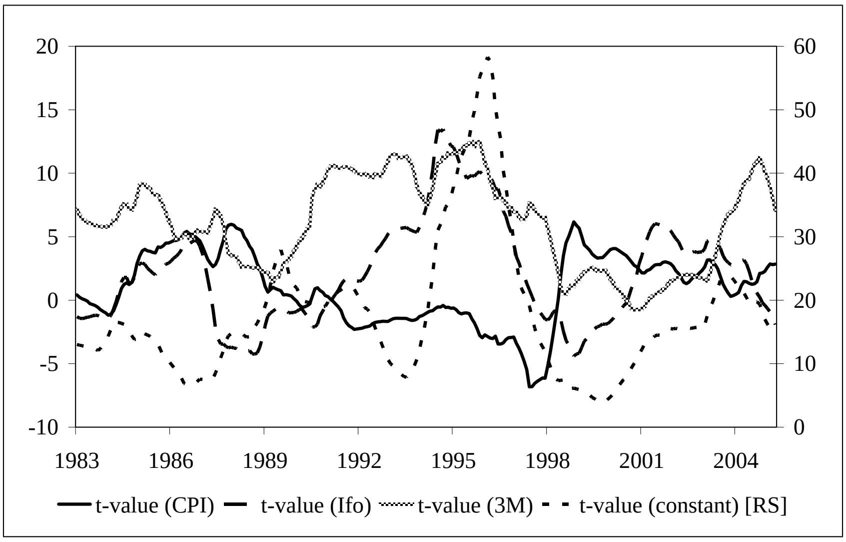

Figure 2.11: Time series of t-values of macroeconomic variables and a constant explaining the long term interest rate (regression 2.17) from July 1983 to October 2005.

macroeconomic variables on the long term interest rate, i.e. the t-values of the rolling windows estimations. The effect of macroeconomic volatility on the long term interest rate can also be found in the Fisher Identity and the Expectations Hypothesis (sections 1.3.2 and 1.3.3). In general, nominal interest rates consist of the expected real interest rate, the expected inflation and the risk premium. Investors demand a higher risk premium to be willing to hold a long term bond during periods of higher realized macroeconomic volatility, because the investors' perception of the uncertainty of future real interest rates and inflation increases in times of high macroeconomic volatility. Nevertheless, the effect of expected GDP and expected CPI on the long term interest rate via the risk premium has a smaller magnitude than the effect via the expected average of short term interest rates. The former effect depends mainly on the volatility (i.e. the second moment of expected GDP and of expected CPI), whereas the latter effect mainly depends on the mean (i.e. the first moment of expected GDP and of expected CPI).

The effect of realized macroeconomic volatility on the impact of macroeconomic variables on the long term interest rate is taken into account by an analysis of the t-values of the moving window regressions of equation 2.17.[24] In this chapter, the realized volatility of a macroeconomic variable M_t at time t over the past 60 periods (including

[24]In contrast to realized volatility, implied volatility is one of the determinants of the price of an option.

period t, i.e. $i = 0, ..., 59$) is defined as:

$$vola(M)_t = \sum_{i=0}^{59} [|M_{t-i} - (60\text{-}month\ moving\ average\ (M))_t|]. \tag{2.19}$$

The realized volatility of the macroeconomic variable M_t is the sum of the absolute deviations of the macroeconomic variable from its 60-month moving average. Preliminary research for this analysis showed that the volatility of the macroeconomic variables is significant in explaining the size and significance of the influence of the macroeconomic variables on the long term interest rate. Consequently, the various t-values of equation 2.17 are explained in an OLS regression by the macroeconomic volatilities of the short term interest rate, the Ifo-Index and the CPI.

In equations 2.20, 2.21 and 2.22, three time series of the t-values of equation 2.17 are explained by realized macroeconomic volatilities of the short term interest rate $vola(3M)_t$, of the CPI $vola(CPI)_t$ and of the Ifo-Index $vola(Ifo)_t$. In equation 2.20, the dependent variable $tvalue(3M, long)_t$ denotes the t-values of the coefficient of the short term interest rate explaining the long term interest rate (First Principal Component). Accordingly, the dependent variables $tvalue(CPI, long)_t$ and $tvalue(Ifo, long)_t$ in equations 2.21 and 2.22 denote the t-values of the coefficient of the CPI and the Ifo-Index explaining the long term interest rate. All realized macroeconomic volatilities are strongly significant, which is indicated by the t-values given in parenthesis.[25] The estimation results have a very low Durbin-Watson statistic, which states a significant positive autocorrelation in the residuals. The positive autocorrelation in the residuals might indicate the presence of an error correction mechanism and the existence of a cointegration relationship between the dependent and explanatory variables.

$$\begin{aligned} tvalue(3M, long)_t &= \underset{(-0.50)}{-0.38} + \underset{(2.69)}{0.02} \cdot vola(3M)_t - \underset{(-6.65)}{0.08} \cdot vola(CPI)_t + \underset{(12.18)}{0.03} \cdot vola(Ifo)_t \\ \overline{R}^2 &= 0.48,\ \text{DW} = 0.03,\ \text{obs.} = 268 \end{aligned} \tag{2.20}$$

[25] Only the constant in equation 2.20 is insignificant.

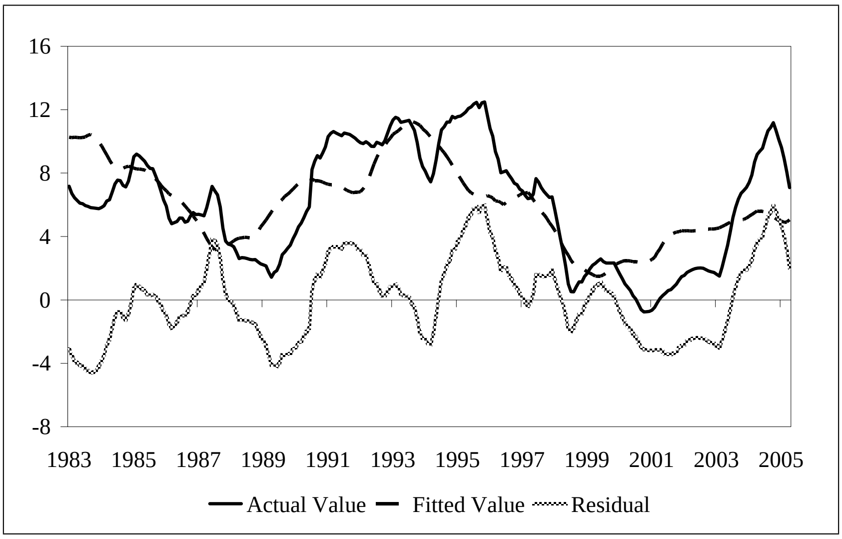

Figure 2.12: Time series of actual values, fitted values and residuals of regression 2.20 which explains the impact (t-value) of the short term interest rate on the long term interest rate by realized macroeconomic volatilities.

$$\begin{aligned} tvalue(Ifo, long)_t &= \underset{(-6.35)}{-5.74} \underset{(-9.14)}{-0.06} \cdot vola(3M)_t + \underset{(2.64)}{0.04} \cdot vola(CPI)_t + \underset{(12.84)}{0.04} \cdot vola(Ifo)_t \\ \overline{R}^2 &= 0.42,\ \mathrm{DW} = 0.02,\ \mathrm{obs.} = 268 \end{aligned} \tag{2.21}$$

$$\begin{aligned} tvalue(CPI, long)_t &= \underset{(5.24)}{3.70} \underset{(-2.60)}{-0.14} \cdot vola(3M)_t + \underset{(5.46)}{0.06} \cdot vola(CPI)_t - \underset{(-6.82)}{0.02} \cdot vola(Ifo)_t \\ \overline{R}^2 &= 0.25,\ \mathrm{DW} = 0.02,\ \mathrm{obs.} = 268 \end{aligned} \tag{2.22}$$

Figures 2.12, 2.13 and 2.14 present the actual values, fitted values and the residuals of the regressions 2.20, 2.21 and 2.22. The time series of the actual and fitted values in all three figures seem to have a comovement in the long term. As they are crossing several times, the time series of the residuals cross the zero line several times. These findings lead to the hypothesis of cointegration between the t-values (the effects of the various macroeconomic variables on the long term interest rate) and the realized macroeconomic volatilities.[26] Accordingly, the residuals seem to be stationary.

[26] Unit root tests of the time series are provided in appendix A.5.

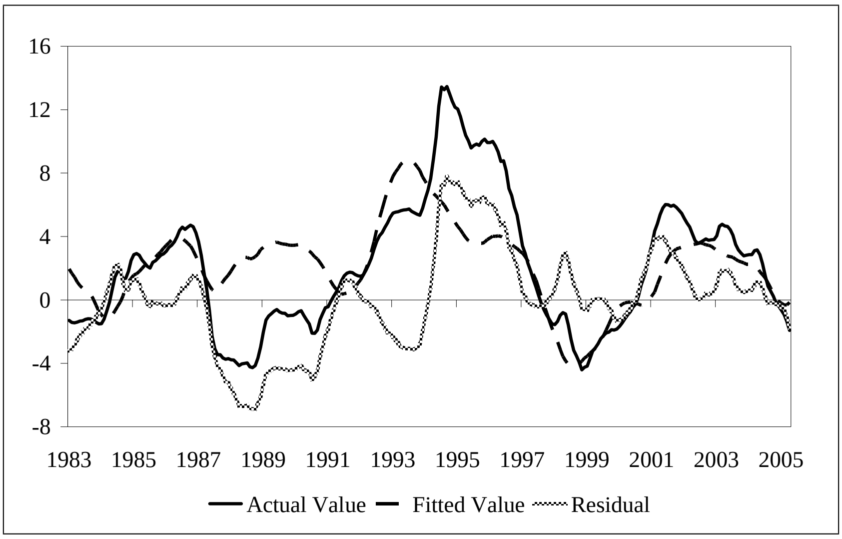

Figure 2.13: Time series of actual values, fitted values and residuals of regression 2.21 which explains the impact (t-value) of the Ifo-Index on the long term interest rate by realized macroeconomic volatilities.

The hypothesis of cointegration between each of the effects of monetary policy (three-month short term interest rate), real activity (Ifo-Index) and inflation (CPI) on the long term interest rate and realized macroeconomic volatility is tested in this section using the approach by Banerjee et al. (1993) and Banerjee, Dolado and Mestre (1998). The approach is used in the empirical macroeconomic literature, for example by Entorf (1998) who researches on the relationship between the market value of stocks and the exchange rate, whereas the relationship depends on the trade balance of the economy.[27]

The test for cointegration by Banerjee et al. is based on an error correction framework. Accordingly, the first difference of a time series of t-values obtained by moving window estimations of regression 2.17 is explained by a regression with a constant, the error correction term and an autoregressive term of the first difference of the t-value. The autoregressive term accounts for the autocorrelation in the time series of the t-values. The test approach by Banerjee et al. for cointegration is based on the t-value of the coefficient of the error correction term, which has to be compared with the critical values provided by Banerjee et al.

Regressions 2.23, 2.24 and 2.25 test for cointegration between the t-values of equation

[27] Entorf (1998) also discusses the advantages of the approach to test for cointegration by Banerjee et al. (1993) in contrast to the approach by Engle and Granger (1987).

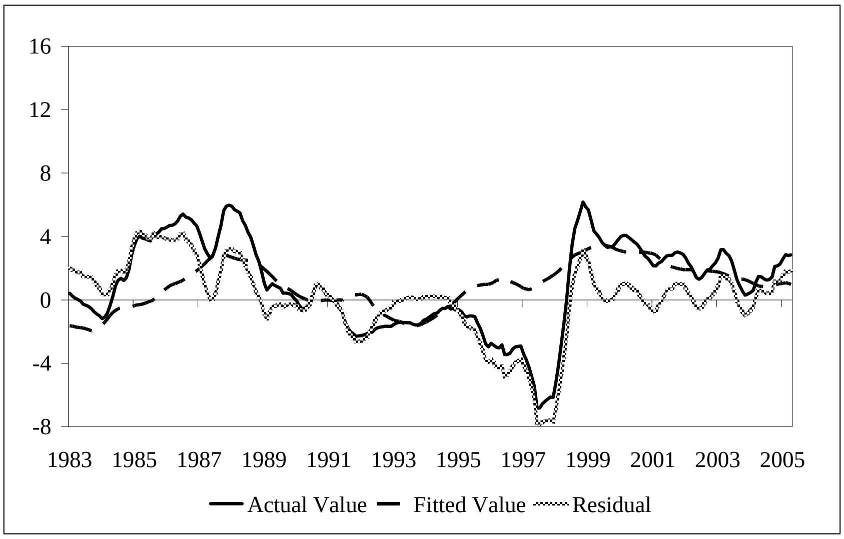

Figure 2.14: Time series of actual values, fitted values and residuals of regression 2.22 which explains the impact (t-value) of the CPI on the long term interest rate by realized macroeconomic volatilities.

2.17 and realized macroeconomic volatility according to the approach by Banerjee et al.[28] The hypothesis of cointegration is tested according to the critical values provided by Banerjee et al. for a single equation error correction framework including a constant. Due to the fact that critical values are provided for single equations including a constant, the constant in the regressions is not omitted even when it is insignificant. The first difference of a time series is denoted by d and t-values are reported in parenthesis.

$$\begin{aligned} d(tvalue(3M,long))_t &= \underset{(0.24)}{0.02} - \underset{(-3.82)}{0.03}[tvalue(3M,long)_{t-1} + \underset{(4.29)}{0.04} \cdot vola(Ifo)_{t-1} \\ &\quad - \underset{(-2.58)}{0.13} \cdot vola(CPI)_{t-1}] + \underset{(14.95)}{0.68} \cdot d(tvalue(3M,long))_{t-1}, \\ \overline{R}^2 &= 0.51,\ \mathrm{DW} = 2.07,\ \mathrm{obs.} = 267. \end{aligned} \tag{2.23}$$

In regression 2.23, the first difference of the t-value $d(tvalue(3M,long))_t$ is explained by a constant, the error correction term which is the residual of the long term relationship (equation 2.20) from the period before, and the autoregressive term of order one $d(tvalue(3M,long))_{t-1}$. The parameter estimate of the error correction term is

[28]The exact specification of the regressions is based on preliminary research. Insignificant variables are omitted, i.e. only significant realized volatilities of the macroeconomic variables are included.

negative (-0.03). Therefore, it fulfils the basic condition of an error correction model. The absolute value of the t-value of -3.82 is larger than the absolute value of the critical value of -3.56 for 100 observations at a significance level of five percent, which is provided by Banerjee et al. for a single equation with a constant and a cointegration relationship that consists of two non-stationary right hand side variables ($vola(Ifo)_{t-1}$ and $vola(CPI)_{t-1}$).[29] Consequently, the cointegration relationship is significant at the five percent level.

$$
\begin{aligned}
d(tvalue(Ifo, long))_t &= \underset{(-1.48)}{-0.09} - \underset{(-3.30)}{0.01}\,[(tvalue(Ifo, long)_{t-1} + \underset{(2.07)}{0.03} \cdot vola(Ifo)_{t-1}] \\
&\quad + \underset{(24.08)}{0.83} \cdot d(tvalue(Ifo, long))_{t-1}, \\
\overline{R}^2 &= 0.69,\ \text{DW} = 1.88,\ \text{obs.} = 267. \qquad (2.24)
\end{aligned}
$$

Regression 2.24 tests for cointegration between the t-values of the Ifo-Index and realized volatility of the Ifo-Index. The parameter estimate of the error correction term is negative (-0.01) and has a t-value of -3.30. The corresponding critical value at the five percent significance level is -3.27, therefore the cointegration relationship is significant. This critical value is different from equation 2.23, because only one non-stationary variable is part of the cointegration relationship (only $vola(Ifo)_{t-1}$ is significant).

$$
\begin{aligned}
d(tvalue(CPI, long)) &= \underset{(2.06)}{0.13} - \underset{(-3.67)}{0.02}\,[(tvalue(CPI, long) - \underset{(-1.99)}{0.02} \cdot vola(Ifo)] \\
&\quad + \underset{(21.65)}{0.80} \cdot d(tvalue(CPI, long))_{t-1}, \\
\overline{R}^2 &= 0.64,\ \text{DW} = 2.01,\ \text{obs.} = 267. \qquad (2.25)
\end{aligned}
$$

The cointegration between the t-values of CPI and realized macroeconomic volatility (equation 2.25) is also significant at the five percent level, whereas the only significant realized macroeconomic volatility in this cointegration relationship is the realized volatility of the Ifo-Index. The t-value of the error correction term is -3.67 and the critical

[29] Only $vola(Ifo)$ and $vola(CPI)$ are included in equation 2.23, because $vola(3M)$ is insignificant.

value is -3.27.

This chapter focuses on the impact of macroeconomic volatility on the effects of the macroeconomy on the long term interest rate, which is the First Principal Component of the term structure of interest rates. The tests for cointegration between the t-values of the macroeconomic variables explaining the long term interest rate and realized macroeconomic volatility show that the effects of the macroeconomy on the long term interest rate are significantly cointegrated with macroeconomic volatility. To research on the effect of macroeconomic volatility on the long term interest rate, this chapter focuses on the analysis of the t-values and does not provide coefficient estimates. The latter would enable a comparison between interest rates implied by the model and actual interest rates.

2.6.3 Estimation of the Slope Factor

To research on the effects of the macroeconomy and its realized volatility on the Second Principal Component of the yield curve, i.e. the spread between the long and short term interest rate (10Y − 3M), it is necessary to explain the three-month money market rate in addition to the long term interest rate (section 2.6.2). The short end of the yield curve in Germany between July 1978 and October 2005 is explained by macroeconomic variables in a Taylor rule for monetary policy. A Taylor rule determines the appropriate target rate of the central bank by the deviation of the current inflation rate from the inflation target of the central bank and the deviation of GDP growth from its potential growth rate (section 2.4.3). Because of the time lag until monetary policy affects the real economy, a central bank specifies the appropriate target rate according to a forward-looking Taylor rule, which is based on the expectations of future inflation and GDP growth.

The Taylor rule consists of macroeconomic data for GDP and inflation. Due to the lack of data for short term inflation expectations for Germany at the beginning of the sample, the contemporaneous inflation rate is used as explanatory variable. Also Sauer and Sturm (2004) use the contemporaneous inflation rate as an approximation for expected inflation, because the central bank decides on monetary policy based on expected values of inflation. The deviation of GDP growth from its potential growth rate (output gap) is approximated by the deviation of the Ifo-Index from its 60-month moving average. The sentiment indicator for the German economy includes an expectations component. Consequently, the expectations of real GDP growth are taken into account by the forward-looking Taylor rule.

To calculate the slope of the yield curve (empirical counterpart of the Second Principal Component), the short term interest rate is explained by a forward-looking Taylor rule and combined with the long term interest rate. The estimation results of the Taylor rule in equation 2.16 ($i_t = c + \beta_\pi \cdot \pi_t + \beta_y \cdot (y_t - y^*) + \xi_t$) are given in equation 2.26, which is estimated with OLS based on 328 monthly observations between July 1978 and October 2005. The short term interest rate i_t is represented by the three-month money market rate $3M_t$, because it is strongly influenced by the target rate of the central bank. Inflation expectations π_t are approximated by the CPI_t. The output gap variable $y_t - y^*$ is calculated as the Ifo-Index Ifo_t relative to its average over the whole sample $mean(Ifo)$ (t-values in parenthesis):

$$\begin{aligned} 3M_t &= \underset{(11.33)}{2.11} + \underset{(21.16)}{1.46} \cdot CPI_t + \underset{(2.90)}{4.33} \cdot (Ifo_t - mean(Ifo)), \\ \overline{R}^2 &= 0.61, \text{ DW} = 0.13, \text{ obs.} = 328. \end{aligned} \tag{2.26}$$

The t-values show that all estimated parameters are significant. The coefficients of the output gap and inflation are positive and therefore in line with economic theory, i.e. an increase in inflation or a GDP growth higher than the potential GDP growth increases the short term interest rate. Based on equation 2.15 ($i_t = (r^* - \gamma_\pi \pi^*) + (1 + \gamma_\pi)\pi_t + \gamma_y(y_t - y^*) + \xi_t$) and on the estimation results of equation 2.26, it is possible to estimate the short term real interest rate r^* for Germany during the period August 1978 to October 2005. Combining $c = r^* - \gamma_\pi \pi^*$ and the estimation results for c (2.11), for $1 + \gamma_\pi$ (1.46) and an inflation target π^* of 2% indicates a real interest rate r^* around 3%.

The residuals of the regression for the short term interest rate (equation 2.26) show a significant positive autocorrelation (the Durbin-Watson statistic is 0.13), because the short term interest rate usually tends to be integrated of order one. As the estimation equation does not include an AR(1) term, the residuals are positively autocorrelated. The reason for the non-stationarity of the short term interest rate might be that both the Deutsche Bundesbank did and the ECB still does interest rate smoothing, i.e. they avoid fast changes between an expansionary and a restrictive monetary policy stimulus. Consequently, interest rates change only slowly.

Sack and Wieland (2000) offer three explanations for interest rate smoothing, which are empirically validated. First, financial market participants are forward-looking. So, forward-looking monetary policy rules which avoid large interest rate movements are more appropriate to influence output and inflation. Second, interest rate smoothing avoids unnecessary movements in output and inflation caused by a central bank which reacts too aggressively to the first announcement of macroeconomic data. As the initial announcement might include an error, it is likely to be revised (especially potential output and the natural rate of unemployment). Third, a slow adjustment of the target rate causes low disruptions in inflation and unemployment, because the effects of discrete monetary policy through transmission channels on the real economy are uncertain.[30]

To integrate interest rate smoothing in the estimation, the following equation of the short term interest rate is used (Sauer and Sturm (2004)):

$$i_t = (1-\rho)\cdot i_t^* + \rho \cdot i_{t-1}, \tag{2.27}$$

where the current nominal short term interest rate i_t at time t gradually converges to the optimal target rate i^*. The adjustment speed is given by ρ (smoothing parameter). The optimal target rate i^* is determined by a Taylor rule (equation 2.16). The combination of equations 2.27 and 2.16 results in equation 2.28 for the short term interest rate based on a Taylor rule and interest rate smoothing, which can be transformed to equation 2.29,

$$i_t = (1-\rho)(r^* - \gamma_\pi \pi^*) + (1-\rho)[(1+\gamma_\pi)\pi_t + \gamma_y(y_t - y^*)] + \rho \cdot i_{t-1} + \xi_t, \tag{2.28}$$

[30] As central banks are deciding as a committee on interest rate decisions, the process of switching to another target rate is slow. This might be another reason for interest rate smoothing, which is not empirically validated (Sack and Wieland (2000)).

$$i_t = (1-\rho) \cdot c + (1-\rho) \cdot [\gamma_\pi \cdot \pi_t + \gamma_y \cdot (y_t - y^*)] + \rho \cdot i_{t-1} + \xi_t. \qquad (2.29)$$

An OLS estimation of equation 2.29 (based on 328 monthly observations) yields the following results (t-values in parenthesis):

$$\begin{aligned} 3M_t &= (1-0.99) \cdot \underset{(-0.36)}{(-2.01)} + (1-0.99) \cdot \left[\underset{(1.49)}{2.52} \cdot CPI_t + \underset{(0.92)}{1.62}(Ifo_t - mean(Ifo))\right] \\ &\quad + \underset{(88.16)}{0.99} \cdot 3M_{t-1}, \\ \overline{R}^2 &= 0.99, \text{ DW} = 1.42, \text{ obs.} = 328. \qquad (2.30) \end{aligned}$$

The inclusion of the autoregressive term $3M_{t-1}$ in the estimation of the short term interest rate $3M_t$ reduces the autocorrelation in the residuals significantly (Durbin-Watson statistic is 1.42). The results show that almost all of the variation in the current short term interest rate is explained by the lagged short term interest rate, if interest rate smoothing is taken into account: only the coefficient of the autoregressive term is significant and has a parameter estimate of 0.99. Consequently, the part of variation in the short term interest rate explained by macroeconomic information becomes negligible and the short term interest rate is only explained according to Time Series Analysis based on its past value. As this chapter researches on an empirical Macro-Finance model of the term structure of interest rates, the short end of the yield curve is modelled by a Taylor rule without interest rate smoothing.

Figure 2.15 shows the t-values of the effects of the business cycle (Ifo-Index), inflation (CPI) and a constant on the short term interest rate estimated by OLS over a rolling window of 60 months of equation 2.26. Even though the t-values of the explanatory variables estimated in the moving window regressions are time-varying, a Cusum of squares test of regression 2.26 over the whole sample signals that the coefficients are stable during the sample (appendix A.4).

Similar to the research on the effect of realized macroeconomic volatility on the impact of macroeconomic variables on the long term interest rate in section 2.6.2, the effect of macroeconomic volatility on the time varying impact of macroeconomic variables on the short term interest rate is analysed according to the approach to test for cointegration by Banerjee et al. (1993) and Banerjee, Dolado and Mestre (1998). The t-values

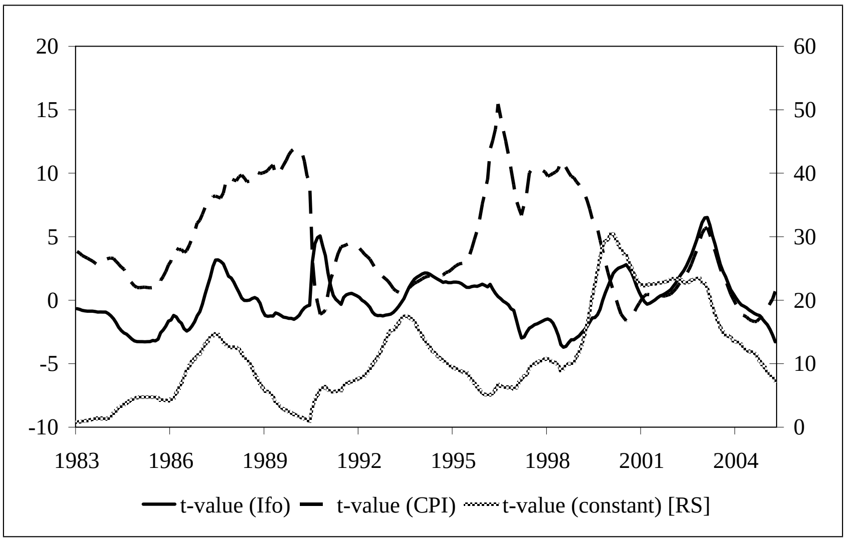

Figure 2.15: Time series of t-values of macroeconomic variables and a constant explaining the short term interest rate (regression 2.26) from July 1983 to October 2005.

of the two explanatory variables in regression 2.26 are explained by realized macroeconomic volatilities, whereas only the variables of macroeconomic volatility are included in the regression which are significant at the five percent level. A constant is included even if it is insignificant in order to make use of the critical values provided by Banerjee et al. to test for cointegration.

Equation 2.31 quantifies the effect of $vola(3M)_t$, $vola(CPI)_t$ and $vola(Ifo)_t$ on the impact of the Ifo-Index on the short term interest rate, i.e. the t-values estimated by a rolling window OLS estimation of equation 2.26. The estimated coefficients of realized volatility of the three-month money market rate, CPI and the Ifo-Index are all significantly different from zero (t-values in parenthesis). Analogous, equation 2.32 states significant effects of $vola(CPI)_t$ and $vola(Ifo)_t$ on the impact of the CPI on the short term interest rate.

$$\begin{aligned} tvalue(Ifo, short)_t &= \underset{(0.89)}{0.44} \underset{(-10.10)}{-0.04} \cdot vola(3M)_t + \underset{(2.72)}{0.02} \cdot vola(CPI)_t + \underset{(4.95)}{0.01} \cdot vola(Ifo)_t \\ \overline{R}^2 &= 0.29, \text{ DW} = 0.06, \text{ obs.} = 268. \end{aligned} \tag{2.31}$$

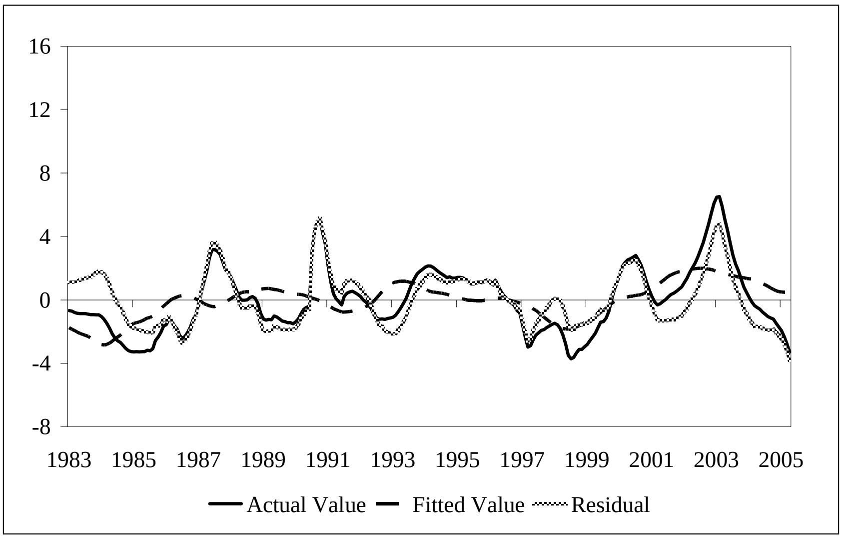

Figure 2.16: Time series of actual values, fitted values and residuals of regression 2.31 which explains the impact (t-value) of the Ifo-Index on the short term interest rate by realized macroeconomic volatilities.

$$\begin{aligned} tvalue(CPI, short)_t &= \underset{(-0.22)}{-0.21} + \underset{(11.60)}{0.15} \cdot vola(CPI)_t - \underset{(-6.55)}{0.02} \cdot vola(Ifo)_t, \\ \overline{R}^2 &= 0.33, \text{ DW} = 0.03, \text{ obs.} = 268. \end{aligned} \qquad (2.32)$$

Figures 2.16 and 2.17 plot the actual and fitted values as well as the residuals of regressions 2.31 and 2.32, respectively. In both figures, the time series of the residuals crosses the zero line several times. This might be an indication of cointegration between the impact of the Ifo-Index on the short term interest rate and realized macroeconomic volatility and of cointegration between the impact of the CPI on the short term interest rate and realized macroeconomic volatility, respectively.

Similar to the analysis of the long term interest rate, the t-values of regression 2.31 and their dependency on realized macroeconomic volatility are analysed in a single equation error correction framework. In equation 2.33, the negative sign of the coefficient of the error correction term (-0.04) signals that there is an error correction mechanism. The corresponding critical value at the one percent significance level reported by Banerjee et al. (1998) is -4.22. Hence, the cointegration relationship is significant due to a t-value of the error correction term of -4.39:

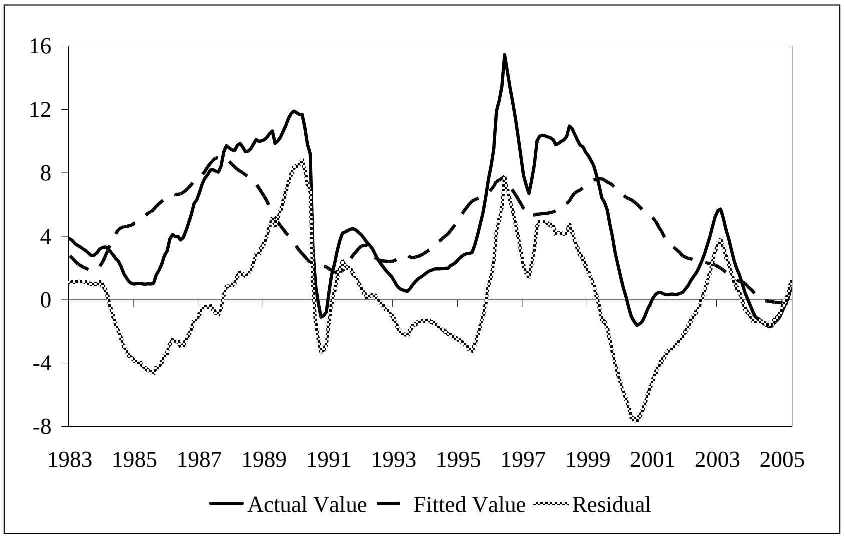

Figure 2.17: Time series of actual values, fitted values and residuals of regression 2.32 which explains the impact (t-value) of the CPI on the short term interest rate by realized macroeconomic volatilities.

$$\begin{aligned} d(tvalue(Ifo, short))_t &= \underset{(0.14)}{0.01} - \underset{(-4.39)}{0.04} [(tvalue(Ifo, short)_{t-1} - \underset{(-2.90)}{0.04} \cdot vola(3M)_{t-1} \\ &\quad + \underset{(1.96)}{0.01} \cdot vola(Ifo)_{t-1}] + \underset{(16.97)}{0.73} \cdot d(tvalue(Ifo, short))_{t-1}, \\ \overline{R}^2 &= 0.52, \text{ DW} = 2.11, \text{ obs.} = 267. \end{aligned} \tag{2.33}$$

Equation 2.34 tests for cointegration between the effect of the CPI on the short term interest rate and realized macroeconomic volatility. As the t-value of the error correction term is -3.38 and the critical value at the five percent significance level is -3.27, this cointegration relationship is significant, too:

$$\begin{aligned} d(tvalue(CPI, short))_t &= -\underset{(-1.37)}{0.17} - \underset{(-3.38)}{0.03} [(tvalue(CPI, short)_{t-1} \\ &\quad + \underset{(2.42)}{0.15} \cdot vola(CPI)_{t-1}] + \underset{(13.52)}{0.64} \cdot d(tvalue(CPI, short))_{t-1}, \\ \overline{R}^2 &= 0.42, \text{ DW} = 2.23, \text{ obs.} = 267. \end{aligned} \tag{2.34}$$

2.6.4 Summary of Estimation Results

Section 2.6.1 presents the estimation results for rolling window regressions of the factor loadings for the First and Second Principal Component on interest rates with different time to maturities.[31] The weight of the First Principal Component (level factor) is around 1 and its time series has a lower variation than the time series of the weight of the Second Principal Component (slope factor). The factor loading of the slope factor depends on the time to maturity of the interest rate: it is about -1 at the short end of the yield curve and slightly smaller than 0 at the long end of the yield curve. The slope factor causes a rotation of the yield curve, because it has a large (negative) impact on the short end of the yield curve and a decreasing impact (in absolute terms) as the time to maturity of the interest rate increases.

The empirical counterparts of the First and Second Principal Component are the long term interest rate and the spread between the long and the short term interest rate (section 2.3). Hence, it is necessary to model the long term interest rate and the short term interest rate to explain the empirical counterparts of the First and Second Principal Component by an empirical Macro-Finance model of the yield curve. The estimation results of the long term interest rate explained by macroeconomic variables (short term interest rate, Ifo-Index and CPI) based on the Expectations Hypothesis are presented in section 2.6.2. The t-values of the macroeconomic variables which explain the long term interest rate are cointegrated with realized macroeconomic volatilities. The t-values of the current short term interest rate, which quantify the magnitude and the significance of the impact of monetary policy on the current long term interest rate, are significantly cointegrated (at the 5% level) with the realized macroeconomic volatility of the Ifo-Index and the CPI. The t-values of the Ifo-Index, which quantify the magnitude and the significance of the impact of output on the current long term interest rate, are significantly cointegrated (at the 5% level) with the realized macroeconomic volatility of the Ifo-Index. The t-values of the CPI, which quantify the magnitude and the significance of the impact of the price level on the current long term interest rate, are also significantly cointegrated (at the 5% level) with the realized macroeconomic volatility of

[31] Two factors (First and Second Principal Component of the yield curve) are sufficient to model the term structure of interest rates (section 2.3).

the Ifo-Index. So, the effect (measured by the t-value) of all macroeconomic variables on the long term interest rate is significantly correlated with the realized macroeconomic volatility of the Ifo-Index. Hence, not only the first moment of macroeconomic variables has a significant and important impact on the long term interest rate, but also the second moment of the path of the real economy.

The findings for the short term interest rate explained by macroeconomic variables based on a Taylor rule in section 2.6.3 are similar to the findings for the long term interest rate. The t-values of macroeconomic variables (output relative to potential output and inflation relative to the inflation target by the central bank), which explain the short term interest rate, are also cointegrated with realized macroeconomic volatilities. The t-values of the current output relative to potential output, which quantify the magnitude and significance of the impact of the real economy on the short term interest rate, are significantly cointegrated (at the 1% level) with the realized macroeconomic volatility of the Ifo-Index and of the short term interest rate. The t-values of the CPI, which quantify the magnitude and significance of the impact of the deviation of inflation from the inflation target on the short term interest rate, are significantly cointegrated (at the 5% level) with the realized macroeconomic volatility of CPI. Analogous to the results for the long term interest rate, realized macroeconomic volatilities of the short term interest rate, Ifo-Index and CPI significantly affect the impact of the real economy (output and inflation) on the short term interest rate.

2.7 Conclusion

The empirical findings state a significant influence of the level (first moment) and realized volatility (second moment) of the real economy, the price level and the short term interest rate on the First and Second Principal Component of the German yield curve. In contrast to the impact of the level of the macroeconomic variables on the yield curve, which is based on macroeconomic theory, the impact of the realized macroeconomic volatility on the yield curve has not been considered in detail in economic research, yet. An exception is the basic principle in Financial Economics that a higher risk, i.e. a higher realized macroeconomic volatility, increases the risk premium demanded by investors. Therefore, the interpretation of the sign and size of the effect of the realized macroeconomic volatilities on the impact (measured by t-values) of macroeconomic variables on the First and Second Principal Component of the term structure cannot be based on a widely accepted economic theory. Due to the strong statistical significance of the empirical results in this analysis, the effect of realized macroeconomic volatility should be part of further research in Financial Economics.

In addition to that, there are other possibilities of further research. Beside the level of the realized macroeconomic volatility, preliminary research for this analysis suggests that the year-on-year change of the realized macroeconomic volatility might also be a significant variable to explain the yield curve. This issue could be included in further research. Another possibility of further research is to focus on the coefficients of the two constituent macroeconomic equations, which explain the empirical counterparts of the First and Second Principal Component of the yield curve. By modelling the coefficients instead of the t-values, this framework of an empirical Macro-Finance model of the yield curve can be used to make forecasts for the level of interest rates. For example, Bandholz, Clostermann and Seitz (2007) use a framework that has similar characteristics to this empirical macroeconomic model of the yield curve, because they also explain the long term interest rate by macroeconomic variables. However, in contrast to this analysis, they estimate the coefficients and can therefore forecast the US long term interest rate by an error correction model. Further research could combine the approach by Bandholz, Clostermann and Seitz to forecast interest rates and the finding of this analysis, that macroeconomic realized volatility has an impact on the effects of macroeconomic variables on the short and long term interest rate.

Chapter 3

Announcement Effects of Macroeconomic News on the Yield Curve

"If I were writing a Ph.D. thesis,
I could explore in great detail the flow of information and
how both short and long rates responded
as new information changed expectations about
inflation, real growth and Fed policy."

— William Poole (2005), President, Federal Reserve Bank of St. Louis

3.1 New Information and Financial Markets

The tremendous increase in global capital flows is one of the main characteristics of globalisation. The integration of financial markets and technological improvements make it easier to invest in a large variety of securities within different asset classes and regions. Consequently, the outstanding volume of assets and the number of global investors has increased remarkably. According to economic theory, investors process all new information correctly and instantaneously. Even though this might not be the case in reality, this assumption of information efficiency is the working hypothesis in Finance and Economics and is called the Efficient Market Hypothesis.[1]

The Efficient Market Hypothesis is based on the investors' information. Theil (1967) defines information "as a change of expectations about the outcome of an event".[2] The arrival of new information forces investors to change their expected probability distribution of the event and therefore new information changes the equilibrium market price. In the following lines of this chapter, information is defined as the surprise component of a macroeconomic data release, i.e. the actual release adjusted for investors' expectations. The Efficient Market Hypothesis has three forms (Campbell, Lo and MacKinlay (1997)). According to the Weak-Form Efficiency, only historical information is available to the investor. The Semistrong-Form Efficiency assumes that the investor is aware of historical information and today's publicly available information. According to the Strong-Form Efficiency, an investor has access not only to historical and publicly available but also to private information.

In this chapter, the Semistrong-Form Efficiency is taken into account when referring to the Efficient Market Hypothesis, because in general it is difficult to include private information into an empirical analysis. Furthermore, this chapter deals with government bond markets which are mainly driven by macroeconomic news that is publicly available information (Das, Ericsson and Kalimipalli (2003)). D'Souza and Gaa (2004) state that

[1]An alternative approach to deal with financial markets is Behavioural Finance that considers that human beings make mistakes, act irrationally and do not always process all available information instantaneously and correctly. An overview of key concepts and major arguments of Modern Finance and Behavioural Finance is given by Andrikopoulos (2005).

[2]Beaver (1968) refers to Theil, H., 1967, Economics and Information Theory, Rand McNally and North Holland Publishing Company.

in periods around the news release, there may also be private information that affects the prices of government bonds. For example, before the release of the macroeconomic announcement, some investors may have information which is not publicly available because of their forecasts based on their market models. After the release, there may be information which is not publicly available due to the fact that market participants may differ in their interpretation of the macroeconomic figures and in their expected impact on the bond market.[3]

The Efficient Market Hypothesis implies that asset prices only change if new information is available to market participants. The new information is the surprise component, that is the difference between the actual release and the investors' expectations. Hence, the expectations have a significant impact on the reaction of financial markets. They can be based on economic theory, technical analysis or on the experience of the investors.

The analysis of the reaction of financial markets to the release of macroeconomic news in this chapter starts with a discussion of the economic relationship between interest rates and the macroeconomy in section 3.2. A survey of event studies on the announcement effects of new information in financial markets is presented in section 3.3. The concept of an event study is introduced in section 3.4, whereas the specific set-up of the event study in this chapter is presented in section 3.5. Section 3.6 gives a detailed description of the data of interest rates, the real-time macroeconomic data and the surprise component of the macroeconomic release. After an analysis of the effects of the release of macroeconomic indicators on the level of different interest rates, announcement effects on the slope and the curvature of the term structure of interest rates are discussed in section 3.7. Section 3.8 concludes and discusses aspects for further research on macroeconomic announcement effects in the bond market.

3.2 Interest Rates and the Macroeconomy

An important part of the interactions of financial markets and the real economy is the relationship between the macroeconomy and interest rates, that is the daily change of the

[3]Investors in the stock and corporate bond market may have private information on firm specific issues like earnings or orders (Christiansen (2000)).

prices of government bonds due to the releases of macroeconomic indicators. Whereas the relationship between bond markets and the macroeconomy has been explored in a medium term perspective in chapter 2, this chapter focuses on the short term perspective by using an event study.

According to Balduzzi, Elton and Green (2001), bond prices move immediately after the release of macroeconomic news because new information affects inflation expectations, which are essential for investors when pricing nominal bonds. As the Phillips curve states that expected inflation is positively correlated with the output, the release of macroeconomic indicators also influences investors' expectations of output. Balduzzi, Elton and Green divide macroeconomic indicators into pro-cyclical and counter-cyclical variables. Pro-cyclical variables are positively correlated with real economic activity and inflation expectations and negatively linked to bond prices (positively to yields). The contrary holds for counter-cyclical variables.

The macroeconomic indicators reflect investors' expectations of future nominal and real interest rates according to the Fisher Identity (section 1.3.2). These expectations of future interest rates are transformed into today's interest rates via the Expectations Hypothesis (section 1.3.3). As a consequence, Andersson, Hansen and Sebastyén (2006) name the Fisher Hypothesis and the Expectations Hypothesis as basic economic theories to deal simultaneously with interest rates and the economy.

$$B_T = E[\sum_{t=1}^{T} \frac{C}{(1+Y_T)^t} + \frac{FV}{(1+Y_T)^T}]. \tag{3.1}$$

They use equation 3.1 which determines the present value B_T of a bond with time to maturity T to show that the bond price is independent of the fixed coupon payments C and the face value FV.[4] So, the bond price only depends on the time-variant discount rate (yield to maturity) Y_T which is influenced by the investors' expectations of future interest rates which in turn are based on macroeconomic indicators. Hence, today's bond prices change when new information about the economic outlook arrives. Another interpretation of equation 3.1 is given by D'Souza and Gaa (2004). They relate macroeconomic news and the price of government bonds via the future costs of capital of an

[4]See Fabozzi (2002) for general aspects of pricing fixed income securities.

investment project, because investors consider the future economic situation in order to forecast the future costs of capital over the time period of the investment project.

3.3 Event Studies on Interest Rates and Macroeconomic News

The empirical event studies in Applied Financial Economics deal with different securities, time horizons, types of news and use different econometric frameworks to quantify the impact. Almost all of them have a positive rather than a normative approach. That is, they focus on how investors actually did react to a news release rather than how investors should have reacted to a news release. One stream in the literature deals with the effects of macroeconomic announcements in financial markets. Another stream analyses the effects of monetary policy decisions and their explanatory statements (e.g. the publication of the minutes of the monetary policy committee meetings, press conferences or press releases) in financial markets. The approach utilized in this chapter follows the former stream, that is it directly measures the effects between the real economy and financial markets. The latter stream only indirectly analyses the effects of the real economy on financial markets, because monetary policy decisions are based on forecasts of the real economy and inflation. Nevertheless, as the short end of the yield curve is highly influenced by monetary policy (Piazzesi (2005)), indirect effects are also implicitly taken into account in this empirical analysis, because monetary policy is based on macroeconomic releases.

One of the first empirical announcement studies is Beaver (1968) who quantifies the impact of earnings announcements in the stock market. Beaver states that the market reactions due to news releases can be tested by using a model for the expectations of the investors. That is, it is possible to quantify the change of the asset price due to the news release by comparing the asset price based on the model for investors' expectations with the movement of the asset price based on the news release. In the analysis, he distinguishes between the market reaction in form of a change of price and a change of volume and finds a significant information content in earnings announcements which influences price and trading volume of stocks. The reason is that the price is based on the expectations of all investors and that the volume is only driven by the expectations of few investors. So, the market price of an asset should be a good approximation for the outcome of the event and should react less to the actual outcome of the event than the volume. The market price of the security changes and the trading volume remains unchanged, if the market as a whole changes its expectations due to the arrival of new information. Contrary, the market price of the security remains unchanged and the trading volume changes, if only a small number of investors change their expectations due to new information. So, an increase in the volume of a traded security implies a "lack of consensus" between investors concerning the price of the asset.

The article by Balduzzi, Elton and Green (2001) confirms that a new equilibrium price does not cause an increase in the trading volume. They find that after an announcement, the trading volume is nearly unrelated to the size of the surprise component, which depends on the expectations of the whole market. This result holds even for types of announcements that have a significant impact on asset prices.

Christie-David, Chaudhry and Lindley (2003) research on the price volatility around the release of macroeconomic news. The surprise in news affects investors' "incentives and motives", because investors who did not expect the actual outcome have new expectations due to the new information. Consequently, they begin to adjust their portfolio by trading after the announcement. The instantaneously increased volatility remains higher than normal for a considerable period of time.

A seminal article in the field of market reactions to news releases is Ederington and Lee (1993) who focus on the impact of 19 US macroeconomic indicators on the fixed income and foreign exchange markets (the Treasury bond, Eurodollar and Deutsche Mark future markets). They observe high market efficiency, because most of the price adjustment takes place in the first minute after the news release and price changes in subsequent minutes are independent of the direction of the price movement in the first minute. So, trading opportunities do only arise within the first minute after the release. Furthermore, they state a higher volatility for "several hours" after the release. However, volatility deviates the most from its normal level during 15 minutes after the announcement. Ederington and Lee find that the employment report is the most significant market mover, followed by the Producer Price Index, Consumer Price Index and Durable Goods Orders.

Andersson, Hansen and Sebestyén (2006) focus on announcement effects of both macroeconomic announcements and news concerning monetary policy by using intraday data. They consider the effects on the level as well as on the variance of the long term yield in the euro area. They find that macroeconomic surprises of US indicators tend to move the European capital markets more than German and European indicators. The influence of the US indicators has even increased in the sample between 1999 and 2005. Furthermore, the level of bond prices reacts very quickly to the surprise component of the announcement. An unexpected outcome of an indicator affects the volatility of European bond yields for a longer period than the level of yields.

Christie-David, Chaudhry and Lindley (2003) focus on the effects of the surprise component in macroeconomic news releases on the price and volatility of futures of the ten-year Treasury Note and of the ten-year Treasury bond.[5] They use 15 minutes intervals of intraday data for the futures and survey data as an approximation for market expectations to determine the surprise component in the news data. They categorize the sign of the surprise as positive (higher prices and lower yields), negative (lower prices and higher yields) or no surprise and the size of the surprise as small, medium, large or no surprise. They run regressions using a dummy variable approach in order to quantify the price change caused by the announcement effect of the aggregated announcements regarding their type and size. In the aggregated analysis, they find that large surprises immediately affect the price and that negative surprises have the longest lasting effects on increasing volatility. Furthermore, in another set of regressions they use a dummy variable approach to analyse separately the price effect of each indicator according to the type or size of the surprise. When analysing each announcement separately, they show in line with other studies that the Employment Report, consisting of Hourly Wages and Non-farm Payrolls, has the largest influence on the bond market, whereas the influence depends on the sign of the surprise: Hourly Wages have the strongest impact in the

[5] Treasury notes have a maturity of two to ten years, whereas Treasury bonds mature in ten years or more. Both are significant indicators for the US bond market. Treasury notes have gained in importance because the issuance of Treasury bonds decreased in the last couple of years.

bond market when the news is positive. When the news is negative, Non-farm Payrolls have the largest effect.

Christie-David and Chaudhry (1999) research on the announcement effects due to the release of macroeconomic news by analysing futures of municipal bonds, Treasury bonds, Treasury notes, Treasury bills and the Eurodollar. These securities can differ in terms of liquidity and maturity. Like other studies, they find a significant reaction of the First and Second moment of the returns of the different futures to the release of macroeconomic data by using a method in line with Ederington and Lee (1993). If the securities are liquid and have a high maturity, they state a more pronounced change of the return and a higher increase in volatility on the announcement day, whereas a high maturity causes the volatility to remain high for a longer period than the liquidity of the asset.

The liquidity of the Canadian bond market measured by immediacy, depth, width and resiliency is the focus of D'Souza and Gaa (2004) who use macroeconomic announcements of the US, Canada and Canadian government bond auctions as news variables. They categorize the macroeconomic announcements into large and small news surprises and find that the Canadian bond market is quick and efficient in processing information.

Christiansen (2000) researches on the effects of macroeconomic announcements on the covariance structure of government bonds, which is also analysed by Jones, Lamont and Lumsdaine (1998). She explains the daily excess return of a government bond over the riskfree rate (i.e. the three-month Treasury bill rate) by a multivariate GARCH model and finds that investors are not compensated for holding a bond on an announcement day, because there is no excess return for a bond on days when uncertain macroeconomic news is released. Further on, she finds that the conditional variance on announcement days is substantially larger (between 122% and 192%), whereas the magnitude depends on the maturity of the bond. The reaction is stronger at the short end of the yield curve than at the long end. Christiansen explicitly deals with the strong correlation of excess returns of bonds with different maturities. In general, the closer the maturities of two different bonds, the higher the correlation between their yields. However, she concludes that yields of all maturities are highly correlated on announcement days, so that the correlation coefficients between yields of different maturities depend less on the maturity.

Balduzzi, Elton and Green (2001) research on the announcement effects of scheduled macroeconomic news (17 indicators) on prices, trading volumes and bid-ask spreads for US government securities with maturities between three months and 30 years. At least one of these US Treasury securities is influenced by the releases of the indicators, whereas the influence strongly depends on the maturity. The price adjustment occurs very quickly in the first minute after the release and the volatility of the prices is mainly due to the surprise component in the news release. In contrast to the bid-ask spread that achieves a normal level in 15 minutes after the announcement, the trading volume and the price volatility remain higher than normal up to 60 minutes after the news release.

Other articles related to announcement effects of macroeconomic news releases and the movement of asset prices are McQueen and Roley (1993), Balduzzi, Elton and Green (1997), Li and Engle (1998), Fleming and Remolona (1999a, 1999b), Ehrmann and Fratzscher (2002), Faust et al. (2003), Goldberg and Leonard (2003), Green (2004), Christiansen and Ranaldo (2005) as well as Andersen et al. (2005).

3.4 Concept of an Event Study

The fundamental idea of an event study is to explain the change of the price of an asset by an event which usually is the arrival of new information in the market. An event study figures out if an investor can earn an unusual return due to the event and if the event forces the return to deviate from a normal level that would have occurred without the event.

The event study presented on the following pages analyses the price changes of German government bonds caused by the release of macroeconomic news, which are the most common economic indicators for the US, Eurozone and German economy.[6] As the three economies are strongly interrelated due to the trade of goods, services and immense capital flows, these macroeconomic indicators affect German government bond prices.

[6]This analysis does not distinguish between the market for government bonds in Germany and in the Eurozone (see section 3.6).

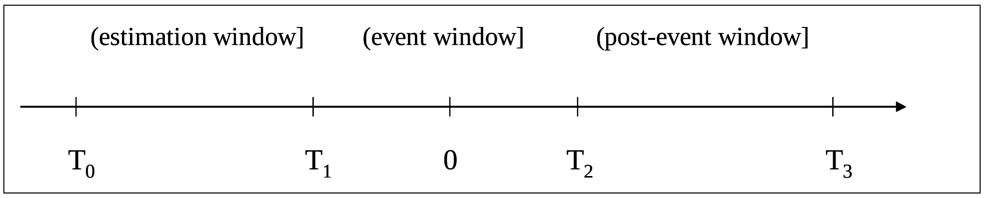

Figure 3.1: Estimation window, event window and post-event window of an event study.

It is essential to adjust the released data by expectations of the market participants, because only surprises in the data release cause asset prices to move. Empirical studies of announcement effects of the release of macroeconomic data quantify changes in financial market variables like prices, returns, volume, volatility and bid-ask spreads due to the surprises in the news releases. When quantifying the changes in returns following a news release, an abnormal return is calculated. That is the difference between the actual return and a counterfactual return without the event taking place.

Early studies of announcement effects deal with the analysis of stock market reactions caused by incoming news (e.g. Beaver (1968)), whereas the price of a stock is influenced by macroeconomic data, balance sheets, regulatory issues and the management. In contrast to that, more recent studies consider various asset classes as dependent variables and various types of news as explanatory variables.[7]

The following presentation of the event study approach is based on MacKinlay (1997). To quantify abnormal returns due to the news release at time 0, it is necessary to quantify the normal return. Hence, in the time period before the event, an estimation window $(T_0, T_1]$ is specified in which the normal return without the event taking place is measured. So, the estimation window yields a return which constitutes the reference value when deciding whether the return is normal or abnormal. At the end of the estimation window, the event window $(T_1, T_2]$ begins during which the news release occurs and the return is affected by the surprise. The abnormal return is the difference between the return observed in the market in the event window and the expected return in the estimation window. After the event window, the post-event window $(T_2, T_3]$ begins. A graphical representation of the different time periods used in event studies is

[7] Andersen et al. (2005) give an overview of the different streams in the literature on announcement effects.

given in figure 3.1.

It is very important to define the time intervals as accurate as possible in order to include all relevant information of the event and to exclude all information which is not related to the event. Only then, it is warranted that the power of the test – that is the ability to detect an abnormal return if there actually is an abnormal return – is as high as possible.

3.4.1 Quantifying the Announcement Effect

Brown and Warner (1980, 1985) propose three useful ways to quantify the abnormal return and test for its significance. The abnormal return Z_{it} of asset i at time t is defined as a prediction error equal to the difference between the actual ex post return observed in the market R_{it} and the ex ante expected return due to the assumed return generating process. In the following lines, different methods to quantify the ex ante expected return are discussed.

When using Mean Adjusted Returns, a time series perspective is taken, that is $\overline{R}_i$ is the average return during the estimation window. The abnormal return Z_{it} is given by

$$Z_{it} = R_{it} - \overline{R}_i. \tag{3.2}$$

Brown and Warner conclude that this test for significance of the abnormal return yields valid results in comparison to more complex methods.

When using Market Adjusted Returns, the abnormal return Z_{it} depends on the return of the market R_{mt} at time t which may be represented by a leading index of this market,

$$Z_{it} = R_{it} - R_{mt}. \tag{3.3}$$

When using an OLS Market model, the expected return of the security R_{it} depends on a constant α_i and depends linearly on the market return R_{mt} with loading β_i. The error term ε_{it} has the characteristics $E(\varepsilon_{it}) = 0$, $Var(\varepsilon_{it}) = \sigma^2_{\varepsilon_i}$ and $Cov(\varepsilon_{it}, \varepsilon_{i,t-s}) = 0$ for all $s \neq 0$. Consequently, the parameters α_i and β_i can be estimated by OLS under the assumption of a normal distribution of the asset returns:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}, \qquad t \in (T_0; T_1]. \tag{3.4}$$

Some empirical articles find that the sample should have an appropriate length for the parameters α_i and β_i to be stationary (for example Binder (1998)). Consequently, the length of the sample interval is chosen to be five or seven years to make α_i and β_i stationary. The OLS estimation yields an ex ante expected return of $\hat{R}_{it}$,

$$\hat{R}_{it} = \hat{\alpha}_i + \hat{\beta}_i R_{mt}, \qquad t \in (T_0; T_1]. \tag{3.5}$$

Hence, the abnormal return Z_{it} is represented by $\widehat{\varepsilon}_{it}$ of the market model:

$$Z_{it} \equiv \widehat{\varepsilon}_{it} = R_{it} - \hat{R}_{it}, \qquad t \in (T_1; T_2]. \tag{3.6}$$

Under the assumption of no structural break between the estimation and event window, the OLS Market model distinguishes whether the return of a single asset R_{it} is due to the market return $\hat{R}_{it}$ or due to the event which is captured in $\widehat{\varepsilon}_{it}$. Another advantage is that the variance of Z_{it} is reduced by the variance of the market return (MacKinlay (1997)): the higher the R^2 in the regression of the market model, the higher the variance reduction of the abnormal return.

After quantifying the ex ante expected return, the abnormal return, i.e. the market reaction due to the news release, is tested for significance. The null hypothesis is $H_0 : Z_{it} = 0$, that is the abnormal return at time 0 is zero. Under the assumption that the abnormal return Z_{it} is independently, identically and normally distributed, the test statistic of a two-sided t-test can be compared with the student's t-distribution:

$$t - statistic = \frac{Z_{it} - 0}{s(Z_{it})} \sim t(n-k), \tag{3.7}$$

where $s(Z_{it})$ is the sample standard deviation of Z_{it} during the estimation window, n the number of observations and k the number of restrictions.

3.4.2 Problems of an Event Study

The event study approach is based on certain assumptions on the properties of the data which may be violated when using financial market data. Nevertheless, even though the number of possible undesirably characteristics of financial market data is large, almost all of the problems can be solved by using an appropriate statistical method. Some of the problems do not decrease the power of the test results, so they can be neglected.

If the event is not included in the event window, the power of the test in an event study is significantly reduced. As macroeconomic news releases are prescheduled, all information content of the event itself as well as of the estimation window can be completely used in the estimation and does not reduce the power of the test.

Another problem when applying an event study to financial market data may arise when a group of related securities is affected by only one news release (Clustering). The overlap of the event windows of different securities leads to a correlation of the price movements between these different securities (MacKinlay (1987)). This is the case for government bonds with different maturities which are analysed in this chapter.[8] The fact that interest rates are correlated when Clustering occurs has two reasons. First, the covariance between the various government bonds is different from zero because all bonds react to the release of macroeconomic news. Nevertheless, the sign and size of the reaction may differ. Second, the price of a security changes when the price of another security within the peer group changes.[9] This chapter presents an event study of the effects of the release of macroeconomic data on the term structure of interest rates. The interest rates of bonds with similar maturities are positively correlated to a high degree. Their reactions to the release of macroeconomic news are also positively correlated. So, in the aftermath of a news release it is not possible to distinguish between the movement of the interest rate due to the news release and due to the correlation between the interest rates.

There is no consensus in the literature on the dimension of the bias when event windows are clustered. Bernard (1987) finds that even in the case of correlated abnormal

[8]The correlation of interest rates of government bonds is analysed in section 2.5.

[9]The interpretation is similar for stocks. For example, a release of a profit warning by one bank affects stock prices within the whole financial sector.

returns, the parameter estimates may be unbiased, but the variance estimate is biased. He points out that the bias of the variance estimate is more severe when using monthly data in contrast to daily data, because the number of daily observations is much larger than the number of parameters to estimate.

Several methods have been used to overcome the estimation problems when financial market reactions are correlated. One solution is to constitute a portfolio of the correlated securities with overlapping event windows (MacKinlay (1997)). However, it is only possible to analyse the aggregated return of this portfolio and the aggregation yields a loss of information and a reduced power of the test. Another solution is to quantify the market reaction by the coefficient of a dummy variable for the event (Binder (1998)). In an equation system, the effect of one event on a number of correlated securities is analysed, so that the sign and size of the reaction of each security can be measured. As the variance covariance matrix is explicitly estimated, the results are reliable.

Another econometric problem of event studies might be the autocorrelation of the abnormal returns due to the news release, which yields biased variance estimates and consequently wrong results of hypothesis tests. Brown and Warner (1985) construct an estimation approach that takes into account autocorrelated abnormal returns and find that the quality of the estimation results improves. Nevertheless, they conclude that autocorrelation plays only a minor role in event studies and can be neglected.

A higher variance during the event window might also pose a threat to the results of an empirical event study. Many return series of financial assets show a significantly increased variance shortly before and after the event. For example, Christie (1983)[10] finds a nearly doubled variance around the event. If the variance used in the test for the abnormal return is estimated within the estimation window without an event, the resulting variance estimate is too low. As a consequence, the standard error is underestimated and the null hypothesis of no abnormal return is rejected too often.

An approach to capture the higher variance around the event for a number of securities that react to the same event is proposed by Boehmer, Musumeci and Poulson (1991). The time series behaviour of the return series during the estimation window is

[10] Brown and Warner (1985) quote Christie, A., 1983, On Information Arrival and Hypothesis Testing in Event Studies, Working Paper, University of Rochester.

left aside. The variance of the price movement on the event day is constructed by using cross sectional data for all the abnormal returns on the event day. However, Brown and Warner (1985) state that if the increase in the variance of the different securities is not the same, the abnormal returns on the event day are not identically distributed and the test statistic is not appropriately specified. In addition to that, due to the cross sectional approach, the increase in the variance is only taken into account if it takes place during the announcement day.

Even though there might be various problems when applying the method of an event study to real data, the results of event studies are very robust. The reason is that either the occurring problems are negligible or the estimation technique can be adjusted for the characteristics of the data.

3.5 Event Study of Macroeconomic News and the Yield Curve

The empirical analysis presents an event study for the secondary market of the German government bond market. As there are strong similarities between the European and the German government bond market, both are considered as equal (section 3.6.1). After German government bonds are issued to institutional investors in the primary market through an auction, they are freely traded in the secondary market and their prices heavily react to macroeconomic news. This price reaction due to a surprise in macroeconomic news is the topic of this event study.[11]

The release of macroeconomic news changes the prices of government bonds. As the pricing formula for fixed income securities (equation 3.1) inversely relates the price of the bond to its interest rate, the daily percentage change of interest rates of a government bond with a certain maturity is taken as dependent variable. Andersson, Hansen and Sebastyén (2006) use intraday data and therefore calculate price changes for five-minute intervals with the logarithms of the corresponding prices to capture continuous time

[11] A different approach has been chosen by D'Souza and Gaa (2004) who analyse the announcement effects on the secondary market for Canadian government bonds caused by auctions on the primary market.

properties of high frequency data. In contrast to that, the discrete daily percentage change of interest rates of government bonds is used as excess return, because this analysis is based on daily data,

$$R_{nt} = (\frac{i_{nt} - i_{n,t-1}}{i_{n,t-1}}) \cdot 100, \tag{3.8}$$

where R_{nt} is the daily percentage change of the interest rate i_{nt} of a government bond with a time to maturity of n years on day t. The daily change of the interest rate of a government bond is measured in percentages rather than in basis points, because the effect in basis points depends on the level of the interest rate.

Although many event studies of financial markets deal with equity markets, the methodology can be applied to bond markets, too. The price change of an asset over a certain period is explained by the surprise component of the announcement. When dealing with interest rates of government bonds, there are three theoretical ways to calculate the dependent variable (excess return due the surprise). One possible way is to take the daily change of the interest rate at the end of a trading day as excess return without any further adjustments. This way of calculation is motivated by the Efficient Market Hypothesis. Accordingly, if there is no arrival of new information in the markets during the trading day, the price of a bond should not change.[12] Another possibility to formulate the dependent variable is to subtract the average return of the security from the actual daily return (Brown and Warner (1980, 1985)). The adjustment of the daily change of interest rates by their historical average daily change would imply a constant flow of information in the markets which is not reasonable. A third possibility is to use the excess return over the riskfree rate as dependent variable (Christiansen (2000)). Hence, the riskfree rate, which is usually represented by a three-month money market rate, is subtracted from the daily change of the interest rate. As the riskfree rate might react as well to the release of macroeconomic announcements, it is difficult to distinguish between the effects of the surprise on the interest rate of the government bond and on the riskfree interest rate.

[12]Price changes during one trading day due to a decline in maturity and accrued interests are neglected as their influence on the price is very small.

Although the last two proposed possibilities can be found in the literature, this empirical analysis uses the first method which is based on the Efficient Market Hypothesis, because the news flow is purely random. So, the expected daily change of interest rates should be zero, which is why it is justified to take the daily change of interest rates without adjustments as the dependent variable. Other related studies like Balduzzi, Elton and Green (2001) and Andersson, Hansen and Sebestyén (2006) also use the unadjusted price change as the dependent variable.

The explanatory variables in this event study are releases of macroeconomic news. According to the Efficient Market Hypothesis, only information which market participants did not expect changes their information set and consequently the market prices. Therefore, it is essential to use only the surprise component of the macroeconomic news S_{it} of indicator i at time t as exogenous variable in an event study. To obtain the surprise component, the actual release of the macroeconomic news A_{it} of indicator i at time t is adjusted by the market expectations E_{it} of indicator i at time t. These market expectations are approximated by a Bloomberg survey which is conducted some days before the release (section 3.6.2). In order to guarantee that the quantified market reaction can be compared for different macroeconomic indicators, the difference between expectations and actual outcome is standardized by the standard deviation of the forecast error σ_i of indicator i over the sample period (Andersson, Hansen and Sebestyén (2006)):

$$S_{it} = \frac{A_{it} - E_{it}}{\sigma_i}. \tag{3.9}$$

Balduzzi, Elton and Green (2001) also use this method to calculate the surprise component and state that the constant standard deviation σ_i over the sample period neither affects the significance of the coefficients nor the fit of the regression. Another method to calculate the surprise component is used by Christie-David, Chaudhry and Lindley (2003). They measure the difference between the forecast and the actual outcome in percentages in order to make the surprises comparable.

To quantify the impact of the release of macroeconomic news on the change of the interest rate of government bonds, the following equation, which is based on Balduzzi, Elton and Green (2001), is estimated:

$$R_{nt} = \beta_0 + \beta_{1i} S_{it} + \sum_{k=1}^{K} \beta_{k+1,i} S_{i_k,t} + e_{it}, \qquad (3.10)$$

where R_{nt} is the daily percentage change of the interest rate of a government bond with a time to maturity of n years at time t (equation 3.8), β_0 is a constant and S_{it} is the surprise component of the macroeconomic release i at time t (equation 3.9). The parameter β_{1i} quantifies the influence of the surprise S_{it} of one standard deviation on the daily percentage change of the interest rate of the government bond R_{nt}. The main focus of this event study is to estimate the parameter β_{1i} and to test for its significance. Due to the fact that in addition to indicator i, other indicators K are regularly or occasionally released on the same day, it is necessary to include the effect of these simultaneously released indicators, too (section 3.4.2). Therefore, the effects of these simultaneously released indicators $\beta_{k+1,i}$ of the surprise components of the simultaneously released indicators $S_{i_k,t}$ are included in the estimated equation by the term $\sum_{k=1}^{K} \beta_{k+1,i} S_{i_k,t}$. The residual e_{it} captures other factors than those included in the regression and is assumed to be normally distributed with mean 0 and variance σ_ϵ^2 ($e_{it} \sim N(0, \sigma_\epsilon^2)$).

Equation 3.10 includes a constant, because a test of significance of the constant analyses whether there is a constant stream of news arriving in the market. Also Fleming and Remolona (1997), Andersen et al. (2005) and Andersson, Hansen and Sebestyén (2006) use a constant in the regression of an event study. Lagged values of the daily percentage change of interest rates are not included in equation 3.10, because the Efficient Market Hypothesis is used as working hypothesis to test for announcement effects. Hence, it is assumed that all relevant information is already included in the asset price and changes in interest rates are only due to – and therefore explained by – the arrival of macroeconomic news. This implies that today's percentage change of the interest rate cannot be explained by the time series of daily changes of interest rates of a government bond.

When estimating equation 3.10, there is a trade-off between including all simultaneously released indicators and having statistically reliable parameter estimates. On the one hand, it is necessary to include all releases of macroeconomic indicators of a trading day to capture all information that influences the interest rate. On the other hand, the number of available observations for an empirical event study is not large enough to include all the simultaneously released indicators. This would result in arbitrary results, because the number of parameters to be estimated would be too large relative to the number of observations.

Therefore, in this event study, the maximum number of simultaneously released indicators that is included in equation 3.10 is three. If there are more than three simultaneously released indicators which are regularly scheduled on the same day, some indicators have to be excluded from the information set. To reduce the number of indicators systematically, indicators from the United States are considered as more important than indicators from the Eurozone, which in turn are more important than German indicators.[13] Similar to Balduzzi, Elton and Green (2001), the necessary condition for an indicator to be considered in the estimated equation as a simultaneously released indicator k is that it is released simultaneously with indicator i at least on ten percent of the announcement days. This restriction avoids that an indicator which is simultaneously released just a few times distorts the sign, size or significance of the estimate of β_{1i}. This determination of the number and type of included releases yields robust and reliable parameter estimates of β_{1i}.

The event study of this chapter is estimated with OLS. To obtain reliable estimation results with OLS, it is necessary to assume that the effects of the surprise components of the macroeconomic announcement on the interest rates (the β coefficients) are constant over the sample period. Balduzzi, Elton and Green (2001) research whether this impact of the macroeconomic surprises on the interest rates is constant. Over a sample of five years, they test if the impact changes over time for each year separately and find only weak evidence for the rejection of the null hypothesis of a stable relationship between macroeconomic surprises and interest rates. That is why they conclude that it is appropriate to assume constant effects. Due to the fact that the sample length of this event study is roughly five years for most of the indicators, the assumption of constant relationships between surprises and interest rates is appropriate.

[13] Within a single economic area, the choice is based on preliminary results.

In general, section 3.4.2 concluded that using OLS as estimation method for an event study yields reliable and robust results even if the data does not fulfil all general conditions for an OLS estimation. An alternative estimation method is Weighted Least Squares. It is used by Ehrmann and Fratzscher (2004) who state that the results obtained by Weighted Least Squares are similar to the results when using OLS.

Beside macroeconomic announcements, there are additional factors that move prices of German government bonds (e.g. statements of central bankers, statistics of monetary aggregates, political events and technical market conditions). However, as it is difficult to obtain quantitative measures of these factors, it is hard to quantify the surprise component of such events. For example, there is no survey available for the statement of a central banker, in which economists and market participants express their expectations concerning how dovish or hawkish the speech of the central banker will be.

In contrast to that, it is possible to quantify the surprise component of interest rate decisions. As most of the central banks conduct monetary policy by setting a target rate for the short term money market rate, financial market participants' expectations of an interest rate decision of a central bank are expressed by money market futures. The surprise component in decisions on monetary policy can be used for empirical event studies (Cook and Hahn (1989), Thornton (1998) and Andersson, Hansen and Sebestyén (2006)).

Nevertheless, the effects of monetary policy decisions on the prices of German government bonds are not explicitly included in this event study. The reason is that today's central banks base their decision on their projections for the economy and on the outcome of the latest economic indicators. As a consequence, decisions on monetary policy do not reveal new information about the macroeconomy and do not influence the prices of government bonds due to new information about the state of the business cycle. Furthermore, central banks try not to surprise financial markets and not to cause price reactions of the financial markets when the actual decision is announced. Therefore, they strongly influence the expectations of financial market participants of the likely path of future interest rates by interviews and speeches in advance of the interest rate decision.[14] However, decisions on monetary policy are implicitly included since the price

[14]The same applies for the release of the minutes of central bank meetings or statements

change of a bond is significantly influenced by the expected effect of the macroeconomic news on future central bank decisions.

A distinctive characteristic of this event study is that the announcement effects of macroeconomic news are separately quantified for interest rates with different maturities. Balduzzi, Elton and Green (2001) also research on announcement effects on bonds with different maturities by using price changes of bonds with other maturities than the dependent variable as additional explanatory variables in equation 3.10. If price changes of bonds with a large difference in maturity relative to the dependent variable are added, the announcement effects are still significant. In contrast to that, if price changes of a bond with a maturity similar to the maturity of the dependent variable are added, the announcement effects are no longer significant. The reason is that bonds with slightly different maturities are significantly higher correlated than bonds with a large difference between their maturities. Consequently, it is hard to figure out whether the price change is due to the news announcement or to the price change of a bond with nearly the same maturity. These findings are in line with the stylised facts of the yield curve presented in section 1.3.1. Balduzzi, Elton and Green (2001) infer from these findings that at least two factors are necessary to model the term structure of interest rates (section 2.3), because changes in interest rates are influenced by two factors: macroeconomic news and the correlation between interest rates with similar time to maturities.

In contrast to other research, the framework of this event study uses standardised surprise components rather than dummy variables to quantify the announcement effect. This has the advantage that it is possible to analyse the announcement effect depending on the surprise component in the news release in terms of the direction and the size of the market reaction. Furthermore, more than one announcement can be considered during the event window (Balduzzi, Elton and Green (2001)).[15]

in press conferences immediately after a monetary policy decision, which give a guidance to investors concerning the next decision.

[15]See Christie-David et al. (2003) for a further discussion of the usefulness of dummy variables as explanatory variables in event studies of price changes in financial markets.

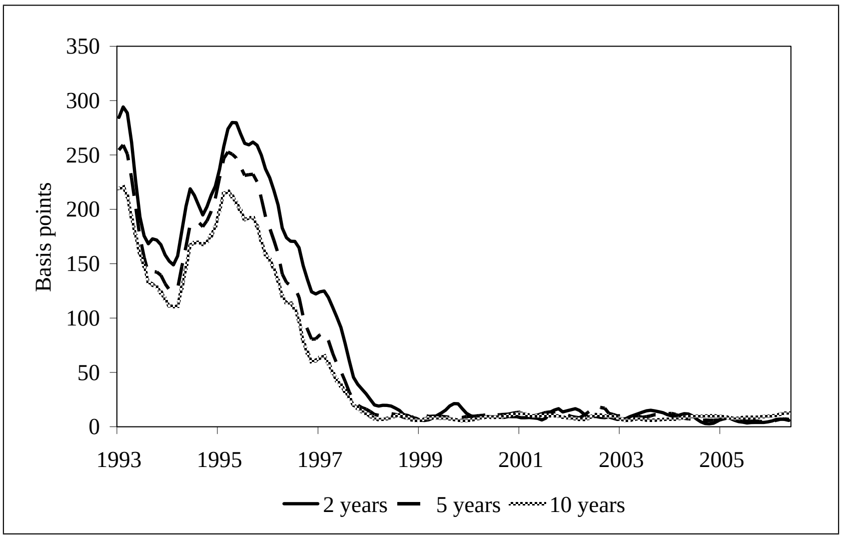

Figure 3.2: Standard deviation (in basis points) of spreads between interest rates of government bonds within the euro area for maturities of two, five and ten years. Source: European Central Bank (2006).

3.6 Data Description

This event study tests the null hypothesis of no market reaction of the German government bond market due to the release of macroeconomic news based on a data set of the surprise component in macroeconomic data and interest rate dynamics. The number of different types of macroeconomic announcements that are considered is large and indicators of different economies (US, Eurozone and Germany) are used as explanatory variables. The comprehensive data set in charge is a distinctive characteristic of this paper.

3.6.1 Interest Rate Data

In this event study, announcement effects of the release of macroeconomic news on the German government bond market are analysed. During the sample of this event study (31 October 1996 to 15 December 2006), the German government bond market is equivalent to the European government bond market. The reason is that the standard deviation of the spread (measured in basis points) between interest rates of government bonds in the euro area with different maturities relative to the European benchmark government bond has converged to a very low level (figure 3.2). The benchmark interest rate for bonds with maturities of two and five years are the interest rates of French government bonds with corresponding maturities and for a maturity of ten years, it is the interest rate of a German government bond. In the euro area, the former national markets for government bonds are highly integrated and there is no difference between the French and German government bond market.

The source of the data for the German bond market is Bloomberg. The daily data gives the quoted interest rates[16] for riskfree government bonds with a maturity from one to ten years.[17] The various time series of the interest rates are financial market quotes of then on-the-run benchmark bonds.[18] As benchmark bonds are typically issued with a time to maturity of years in whole numbers, the constructed time series contain information about interest rate dynamics for generic constant maturity bonds. Hence, these generic bonds do not suffer from a decline in maturity and are therefore suitable for comparisons between different points in time. Descriptive statistics for the level of interest rates as well as for the daily percentage change of interest rates used in the event study are given in the appendix B.1.1.

In contrast to this analysis, some event studies use futures on bonds to measure the price movements in the bond market, because futures are traded for a longer period on a trading day. Furthermore, the nearby future contract is nearly perfectly correlated with the corresponding security on the spot market and future markets for sovereign bonds are very deep (Ederington and Lee (1993)). However, futures have delivery options that have to be considered in an event study and they do not have bid-ask spreads to analyse the news effect on liquidity (Balduzzi, Elton and Green (2001)).

The interest rates of government bonds which are used in this event study also have an influence on risky fixed income securities. The reason is that government bonds are the benchmark for the pricing and hedging of risky fixed income securities, because they are considered to be virtually default-free (D'Souza and Gaa (2004)). Furthermore, government bonds can be dealt quickly and with very small transaction costs.

[16] The term "interest rate" refers to the yield to maturity of the bond.

[17] Bloomberg calculates the average of at least two most recently market maker bid-side quotes for the generic interest rate data.

[18] An on-the-run bond is the current benchmark bond in the market until a new benchmark bond is issued and the former benchmark bond becomes an off-the-run bond (Fabozzi(2002)).

Recent articles on announcement effects of macroeconomic news releases on financial markets find that almost all of the price adjustment takes place during the first minute after the scheduled macroeconomic announcement and that this price jump is often a very good approximation for the new equilibrium price (section 3.3). Consequently, these studies use intraday data which is often spaced in intervals of five minutes. In contrast to that, this event study uses daily data of changes of interest rates of government bonds. Hence, only changes of interest rates that are at least persistent until the end of the trading day are analysed. The reason why the price might react later than one minute after the release is that investors have different abilities, models, experiences and time restrictions. D'Souza and Gaa (2004) state that there might be a time interval larger than five minutes until the new information is included in the market prices.

3.6.2 Macroeconomic Surprise Data

In general, the outcome of macroeconomic announcements is independent of the time of release of the indicator.[19] In an event study, it is important to know the exact date and time of the release of the macroeconomic news which is the case for macroeconomic indicators, because their release is scheduled.[20] Therefore, it can be guaranteed that the event window includes the event which avoids a reduction of the power of the test of an abnormal return when quantifying the announcement effect (section 3.4).[21]

[19] In contrast to macroeconomic indicators, the outcome of firm specific news that arrive in the stock market can be correlated with the time of the release. For example, companies tend to release good results earlier than results that do not meet analysts' expectations.

[20] For some German indicators, only a range of some days is scheduled for the release.

[21] The same applies to releases that are equally sequenced over time and therefore their time and date of announcement is exactly known (Christie-David et al. (2003)).

Indicators of Real Activity	Price Indicators	Sentiment Indicators
Current Account (56)	CPI, final, mom (47)	Ifo-Index (33)
Exports (34)	CPI, final, yoy (45)	ZEW-Index (58)
GDP, final, qoq (37)	Import Prices, mom (86)	
GDP, final, yoy (26)	Import Prices, yoy (86)	
Industrial Orders, mom (95)	PPI, mom (116)	
Industrial Orders, yoy (19)	PPI, yoy(116)	
Industrial Prod., mom (114)		
Industrial Prod., yoy (19)		
Retail Sales, mom (98)		
Retail Sales, yoy (115)		
Trade Balance (55)		
Unemployed (90)		
Unemployment Rate (96)		

Table 3.1: German indicators used in the event study (number of observations in parenthesis).

Indicators of Real Activity	Price Indicators	Sentiment Indicators
Current Account (16)	CPI, prel., yoy (58)	Consumer Confid. (42)
Labour Cost Index (16)	CPI, final, mom (67)	Business Confid. (43)
GDP, final, qoq (23)	CPI, final, yoy (68)	ESI (41)
GDP, final, yoy (23)	PPI, mom (64)	
Industrial Orders, mom (33)	PPI, yoy (64)	
Industrial Orders, yoy (32)		
Industrial Prod., mom (67)		
Industrial Prod., yoy (66)		
Retail Sales, mom (62)		
Retail Sales, yoy (62)		
Trade Balance (17)		
Unemployment Rate (78)		

Table 3.2: Eurozone indicators used in the event study (number of observations in parenthesis).

The set of indicators includes sentiment indicators, indicators of real activity and price indicators. Tables 3.1, 3.2 and 3.3 show the set of macroeconomic indicators that are used in this event study for the economies of Germany (21 indicators), the Eurozone (20 indicators) and the US (35 indicators). The source of the actual releases of the outcome of the indicators in this event study is Bloomberg.

In efficient financial markets, only the surprise component in the release of macroeconomic indicators causes a market reaction (section 3.1). McQueen and Roley (1993) are one of the first who explicitly use the surprise component in the news release in their event study. They gauge the market expectation by surveys on the outcome of the event and adjust the information which arrives in the market by prior expectations of market participants.

This event study uses the median of Bloomberg surveys to approximate the market expectation of the outcome of the release of a certain macroeconomic indicator. These surveys are available to all Bloomberg users. Bloomberg questions Economists in the financial services industry every Friday concerning their expectations of the macroeconomic variables that are due to be released in the week ahead.[22] As the analysts can change their forecasts until the news is released, the exact day of the survey cannot be stated. The number of survey participants varies significantly between 15 and 70 or more.[23]

For the calculation of the surprise component in this event study, the forecasts of the analysts should be unbiased (Christie-David, Chaudhry and Lindley (2003)). Otherwise, the release of an indicator causes a market reaction, even when there is no new information in the data. The reason is that analysts perceive the outcome of the indicator as a surprise due to their systematically inappropriate forecasts. To test for unbiased expectations, Andersson, Hansen and Sebestyén (2006) propose to explain the actual outcome A_{it} of indicator i at time t by a constant α_i and by the expectations of the analysts E_{it} (equation 3.11). If the expectations are unbiased, the estimated value of the constant α_i has to be zero and the coefficient estimate of the survey forecast β_i has

[22]There might be a difference between the expectations of direct market participants (e.g. traders and portfolio managers) and indirect market participants (e.g. analysts and economists), whereas only the latter are included in the survey.

[23]Descriptive statistics of the analysts' forecasts can be found in appendix B.1.2.

Indicators of Real Activity	Price Indicators	Sentiment Indicators
Auto Sales (48)	CPI (120)	Consumer Confidence (118)
Average Hourly Earnings (102)	CPI Core (118)	Empire State Index (50)
Business Inventories (114)	PCE Core (27)	ISM Manufacturing (122)
Capacity Utilisation (120)	PPI (108)	ISM Non-Manufacturing (95)
Current Account (35)	PPI Core (120)	Leading Indicator (118)
Durable Goods Orders(109)		Philadelphia Fed Index (119)
GDP, final (38)		PMI Chicago (118)
Housing Permits (52)		Help Wanted Index (47)
Housing Starts (105)		Uni. of Michigan, final (91)
Industrial Prod., mom (121)		
Industrial Orders, mom (122)		
Initial Claims (494)		
Non-Farm Payrolls (120)		
Personal Income (121)		
Personal Spending (119)		
Productivity, final (36)		
Retail Sales (67)		
Retail Sales ex. autos (67)		
Trade Balance (121)		
Unemployment Rate (121)		
Unit Labour Costs, final (30)		

Table 3.3: US indicators used in the event study (number of observations in parenthesis).

to be one. Hence, this test procedure is a Wald test of the joint significance of $\alpha_i = 0$ and $\beta_i = 1$ in equation 3.11 which is estimated with OLS:

$$A_{it} = \alpha_i + \beta_i E_{it} + \epsilon_{it}. \tag{3.11}$$

The results of the Wald tests are presented in table 3.4 for Germany, in table 3.5 for the Eurozone and in table 3.6 for the US. For Germany, the null hypothesis of unbiased forecasts has to be rejected at the five percent level of significance for twelve of 21 indicators. For the Eurozone, the null hypothesis has only to be rejected for two of 20 indicators and for the United States, analysts have biased expectations of 14 of 35 indicators. All in all, the analysts' forecasts are not unbiased for 37% of the macroeconomic releases of this event study.

It is a distinctive characteristic of this event study that the releases of the macroeconomic indicators are real-time data, that is revisions of the initially released data

Germany	Wald test p-value	Observations
Current Account	0.0091	56
Exports	0.0246	34
GDP, preliminary, qoq	0.8677	37
GDP, preliminary, yoy	0.0000	26
Industrial Orders, mom	0.1365	95
Industrial Orders, yoy	0.3250	19
Industrial Production, mom	0.1000	114
Industrial Production, yoy	0.1315	19
Retail Sales, mom	0.0238	98
Retail Sales, yoy	0.0272	115
Trade Balance	0.0005	55
Unemployed	0.0101	90
Unemployment Rate	0.0036	96
Consumer Prices, mom	0.5658	47
Consumer Prices, yoy	0.4659	45
Import Prices, mom	0.0000	86
Import Prices, yoy	0.0090	86
Producer Prices, mom	0.0049	116
Producer Prices, yoy	0.0033	116
Ifo-Index	0.0549	33
ZEW-Index	0.4744	58

Table 3.4: Results of testing for a bias of analysts' forecasts for German indicators.

are not included in the data set. If a market reaction is quantified without real-time data, the data used in the event study might differ from the data that was initially released.[24] Accordingly, there might be a loss of information and the results might be biased.[25] The concept of real-time data is important in Empirical Macroeconomics and Empirical Finance. For example, Orphanides (2003) uses real-time data and a Taylor rule to explain monetary policy.

[24]In many empirical event studies, the revisions of the data are not considered in the analysis because it would be a problem to separate the announcement effect due to the most recent announcement and due to the revision of earlier announcements.

[25]An example for a revision of last month's data that had a large and significant impact on financial markets is the employment report on October 6, 2006. The increase of the benchmark yield for US government bonds during this trading day was nine basis points. The reason for this was – beside an unexpected drop in the unemployment rate – that the non-farm payrolls for the month before were revised upwards by 60.000 to 188.000 (Bloomberg (2006)).

Eurozone	Wald test p-value	Observations
Current Account	0.1875	16
Labour Cost Index, qoq	0.5014	16
GDP, advance, qoq	0.5637	23
GDP, advance, yoy	0.2987	23
Industrial Orders, mom	0.6518	33
Industrial Orders, yoy	0.2492	32
Industrial Production, mom	0.0584	67
Industrial Production, yoy	0.9672	66
Retail Sales, mom	0.5257	62
Retail Sales, yoy	0.0826	62
Trade Balance	0.4332	17
Unemployment Rate, mom	0.0848	78
Consumer Prices, preliminary, mom	0.0656	58
Consumer Prices, final, mom	0.4497	67
Consumer Prices, final, yoy	0.5707	68
Producer Prices, mom	0.4596	64
Producer Prices, yoy	0.0926	64
Business Confidence	0.0352	43
Consumer Confidence	0.0029	42
ESI	0.0903	41

Table 3.5: Results of testing for a bias of analysts' forecasts for Eurozone indicators.

The degree of a possible revision after the initial release depends on the indicator. Whereas some indicators like the ISM index are never revised, other indicators are revised at each announcement up to two previous months. This is the case for Durable Goods Orders and the Employment Report which consists of the monthly change of Non-Farm Payrolls, the level of the Unemployment Rate and Average Hourly Earnings. Some indicators are revised once a year in a benchmark revision, for example the seasonality factors in the Consumer Price Index.[26]

[26] Business cycle indicators that are revised at every announcement for the last months might also underlie benchmark revisions once a year.

USA	Wald test p-value	Observations
Auto Sales	0.0140	48
Average Hourly Earnings	0.6922	102
Business Inventories	0.1428	114
Capacity Utilisation	0.9929	120
Current Account	0.9072	35
Durable Goods Orders	0.0004	109
GDP, final	0.9878	38
Housing Permits	0.2773	52
Housing Starts	0.1421	105
Industrial Production, mom	0.0158	121
Industrial Orders, mom	0.2146	122
Initial Claims	0.2516	494
Non-Farm Payrolls	0.0661	120
Personal Income	0.1391	121
Personal Spending	0.0007	119
Producitivity, final	0.0752	36
Retail Sales	0.0118	67
Retail Sales ex. autos	0.0138	67
Trade Balance	0.6559	121
Unemployment Rate	0.0060	121
Unit Labour Costs, final	0.4965	30
CPI, mom	0.0000	120
CPI Core, mom	0.0270	118
PCE Core	0.4192	27
PPI	0.0000	108
PPI Core	0.1606	120
Consumer Confidence	0.6799	118
Empire State Index	0.0889	50
ISM Manufacturing	0.9885	122
ISM Non-Manufacturing	0.0703	95
Leading Indicator	0.0000	118
Philadelphia Fed Index	0.5005	119
PMI Chicago	0.4869	118
Help Wanted Index	0.0015	47
University of Michigan, final	0.0000	91

Table 3.6: Results of testing for a bias of analysts' forecasts for US indicators.

3.7 Estimation Results

The results of this event study quantify the sign, size and significance of the impact of the surprise component in macroeconomic indicators on the German term structure of government bond yields. The expectations of the sign of the impact of the several macroeconomic indicators are based on the second chapter which deals with the macroeconomic determinants of the term structure of interest rates in the medium term. Accordingly, the impact of indicators for real activity and sentiment indicators should be positive. That is, a better than expected economic situation should cause an upward movement of interest rates and vice versa. The same applies for the impact of price indicators: a higher than expected development of prices should cause interest rates to move upwards and vice versa.

The effects of German, European and US macroeconomic indicators on the interest rate of German government bonds with maturities between one and ten years are presented in section 3.7.1. Furthermore, the effect of macroeconomic news on the slope and curvature of the German yield curve for government bonds is described in section 3.7.2.[27]

3.7.1 Announcement Effects on the Level of Interest Rates

3.7.1.1 German Macroeconomic Indicators

As global financial markets are becoming more and more integrated, the market for German government bonds is driven by the same information and news that influence global asset prices. This implies that the German economy is only one driver of the German bond market. Hence, the impact of German indicators is small.

The results of all German indicators are presented in appendix B.2. This event study finds no significant influence of German indicators for real economic activity on any interest rate of German government bonds with a maturity between one and ten years.[28] So, financial market participants do not consider recent releases of German

[27] All macroeconomic indicators that significantly affect at least three maturities of the yield curve are plotted in section 3.7.1 or in appendix B.4.

[28] The only exception is the Industrial Production (yoy), which will be discussed below.

indicators for real economic activity when pricing German government bonds in the short term. Neither do financial market participants consider German price data: German consumer, import and producer prices do not influence German government bond yields in the short term. One reason is that the decisions of the ECB on interest rates depend on the economic situation and price development in the whole euro area.[29]

Nevertheless, there are two German sentiment indicators – the Ifo-Index and ZEW-Index – that have an impact on the market for German government bonds. Both are sentiment indicators based on surveys and have good reputations due to their ability to forecast the future path of the German economy. The Ifo-Index with 33 observations has the largest impact on the market, whereas it has the expected positive effect, as a higher real economic activity in Germany increases the level of German interest rates. The magnitude of the impact of the Ifo-Index on the daily percentage change of interest rates of German government bonds with maturities between one and ten years is displayed in figure 3.3. The ordinate denotes the daily percentage change of the corresponding interest rates due to a surprise of one standard deviation in the release of the indicator. The impact of the Ifo-Index on government bonds with maturities between one and nine years is always significant at the one percent level. For bonds with a maturity of ten years, the p-value of 0.012 indicates significance just above the one percent level. A surprise of one standard deviation in the Ifo-Index has the largest impact on the interest rates of bonds with maturities of two and three years. For both maturities, the daily change of the interest rate is slightly greater than 0.7%. For larger maturities, the effect declines steadily to slightly below 0.4% at a maturity of ten years. The impact of a surprise of one standard deviation in the Ifo-Index on the one-year interest rate is about 0.15 percentage points lower than on the two-year interest rate. The reason is that the Ifo-Index is a leading indicator for the real economy with a time lag of several months.

According to the definition of the surprise component of a macroeconomic indicator in this event study, the surprise is measured in terms of the standard deviation of the

[29] Due to the availability of the data for this event study, the surprise components in the releases of some indicators are based on the final releases and not on the preliminary releases (German CPI and GDP, European GDP and US GDP, Productivity, Unit Labour Costs and Consumer Confidence of the University of Michigan). The statistical results for the preliminary releases might be different.

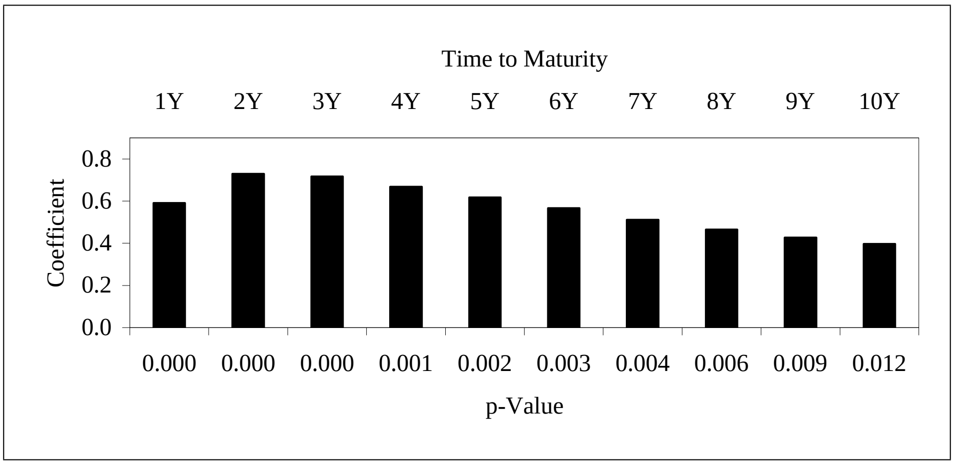

Figure 3.3: Announcement effect of the Ifo-Index on interest rates of German government bonds with maturities between one and ten years.

forecast error for this indicator. To interpret the coefficients of the surprise component of the several macroeconomic releases, their standard deviations of the forecast errors of German, European and US indicators are presented in appendix B.3. The better the quality of the prediction by the survey participants, the smaller is the standard deviation of the forecast error. For the Ifo-Index, one standard deviation is equal to a forecast error of the survey of 1.15. For example, an actual outcome of 105.15 for a forecast of 104.0 yields the bond market reaction depicted in figure 3.3. This interpretation of the coefficients is also used by Balduzzi, Elton and Green (2001).

The second significant market mover of German sentiment indicators is the ZEW-Index. Its impact on the German bond market is displayed in figure 3.4. A positive surprise of one standard deviation in the ZEW-Index has the expected positive effect on the yield curve for German government bonds. The magnitude of the impact of the ZEW-Index is smaller than of the Ifo-Index for all maturities between one and ten years. Both the Ifo- and the ZEW-Index have their strongest impact on bonds with maturities between two and five years.

The only significant (at least at the ten percent level) indicator for German real economic activity is the Industrial Production (yoy) which significantly influences bonds with a maturity of one year. The coefficient is -0.9 and its p-value 0.072.[30] However,

[30] As the Industrial Production (yoy) only significantly affects German government bonds with a time to maturity of one year, a figure for this indicator is omitted.

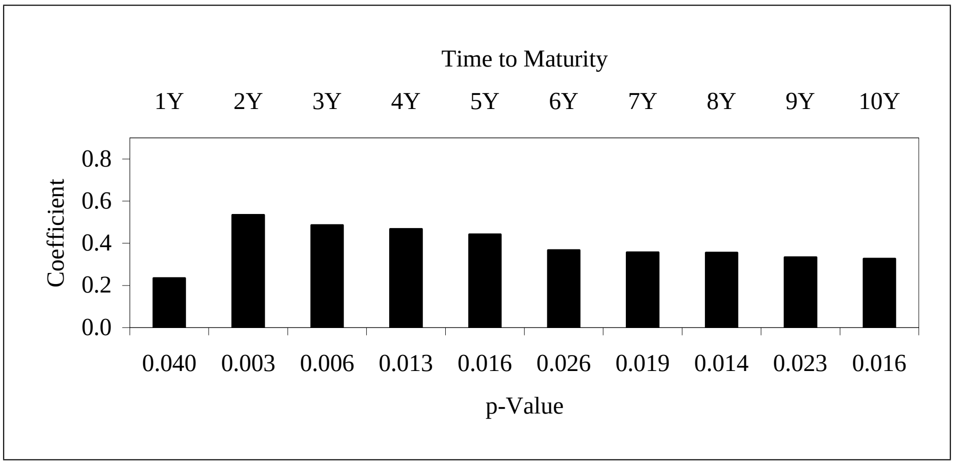

Figure 3.4: Announcement effect of the ZEW-Index on interest rates of German government bonds with maturities between one and ten years.

the sign of the coefficient should be positive according to economic theory. The reason for the negative sign might be that there are only 19 observations for German Industrial Production and that the US Employment Report, which has a strong impact on global bond markets, has been released four times simultaneously.

3.7.1.2 European Macroeconomic Indicators

In general, the effects of European macroeconomic indicators are larger than of German indicators. The estimation results of this event study for the European indicators are summarized in appendix B.2. Some of the European indicators for real activity have significant effects on the German government bond market.

The Current Account of the Eurozone has a significant influence at the ten percent level on yields with maturities of one, three and four years, whereas the magnitude of the estimated impact of a positive surprise of one standard deviation on the Current Account is negative between -0.4% and -0.8% (figure B.1 in appendix B.4.1).[31] The negative sign of the coefficients has been expected due to economic theory, as an increase in the Current Account displays a higher increase in demand from abroad than in domestic demand. This might signal a down-swing in the domestic business cycle in line with lower yields at the short end of the yield curve.

[31] The effect on bonds with a maturity of five years is almost significant at the ten percent level (p-value of 0.101) and has a coefficient of -0.540.

The Labour Cost Index has a significant influence on the German yield curve between a maturity of two and ten years, whereas the influence is the strongest in the middle of the yield curve (figure B.2 in appendix B.4.1). The negative sign of all significant coefficients is surprising, because a higher than expected pressure in labour costs should result in higher short term interest rates. The reason is that a forward-looking central bank should raise interest rates in order to prevent secondary effects, for example a higher inflation in consumer prices due to higher wages. Nevertheless, the robustness of the results suffers from only 16 observations for this indicator.

In contrast to economic theory, the year-on-year change of Industrial Orders in the Eurozone has a significant negative influence on nearly the whole maturity spectrum of the German yield curve (figure B.3 in appendix B.4.1).[32] In contrast to the year-on-year rate, the month-on-month change is not taken into account by market participants as all coefficients for the month-on-month changes of Industrial Orders are insignificant. As only the year-on-year change is significant and the sign of the coefficients is negative, it might be the case that bond investors anticipate an economic downswing in the following years after an unexpected positive surprise in the year-on-year change of Industrial Orders. An unexpected increase in Industrial Orders might signal that the economy is close to the peak of the business cycle.

Beside the European indicators for real economic activity, the price indicators for the euro area are analysed in this event study, whereas market participants differently judge the impact of consumer and producer prices. The impact of the Consumer Price Index on the bond market is insignificant for the preliminary and final release of the year-on-year change (figure B.4 in appendix B.4.1). In contrast to that, the final release of the month-on-month change is significant for seven of ten maturities, whereas these significant impacts are slightly stronger on bonds with maturities up to five years than on bonds with maturities between six and ten years. The positive signs of the impact of a positive surprise in the month-on-month change of consumer prices are in line with economic theory, as the central bank will raise the short term interest rate to reduce the inflationary pressure.

[32] Only for maturities of three and ten years, the impact of the year-on-year change of Industrial Orders is not significant.

The impact of a surprise in the Producer Price Index is significant for all maturities both for the month-on-month change and for the year-on-year change (figures B.5 and B.6 in appendix B.4.1). The impact of the month-on-month change of the surprise in producer prices on the German yield curve is positive, which is in line with economic theory. The impact has the largest magnitude on maturities between two and five years. In contrast to that, the estimated impact of the year-on-year change of producer prices is negative, which contradicts economic theory.

Both European sentiment indicators included in this event study have a strong impact on the German bond market. The Business Confidence Indicator has a significant and negative influence on the whole yield curve, whereas the influence is largest for a maturity of two years (figure B.7 in appendix B.4.1).[33] The negative estimates for the coefficients are not in line with economic theory, because a positive sentiment within the economy should precede higher real activity and therefore higher interest rates.

The European Sentiment Indicator has a significant influence on the whole term structure of interest rates of German government bonds (figure 3.5). In addition to that, the magnitude of its impact is high. For example, the impact of a positive surprise in the European Sentiment Indicator of one standard deviation results in a change of the yield of a two-year bond of nearly 0.9%. Five of ten maturities move by more than 0.5% during a trading day when the European Sentiment Indicator is released.

[33] Only for a maturity of four years, the impact of the Business Confidence Indicator is not significant.

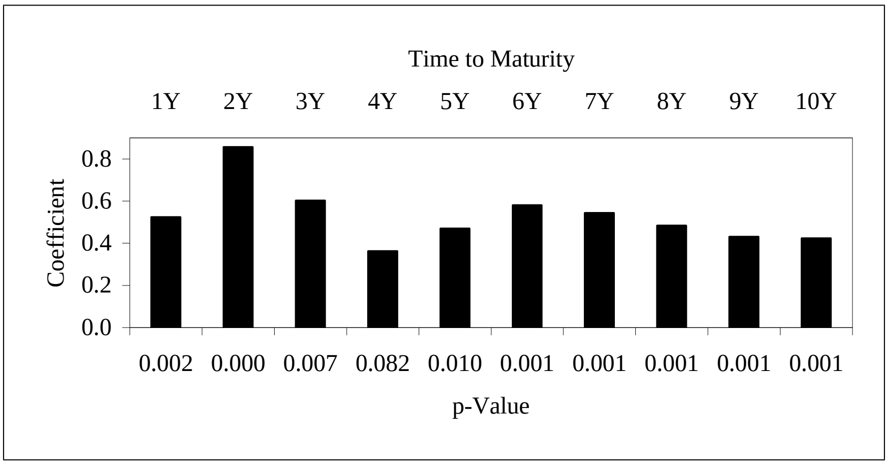

Figure 3.5: Announcement effect of the European Sentiment Indicator on interest rates of German government bonds with maturities between one and ten years.

3.7.1.3 US Macroeconomic Indicators

The estimation results of this event study confirm the large impact of US macroeconomic indicators on the German market for government bonds. The Employment Report consists of the releases of Average Hourly Earnings, Non-Farm Payrolls and the Unemployment Rate. The former two are one of the strongest market movers, whereas the Unemployment Rate does not have a significant impact on the German bond market. The impact of a surprise in the release of Average Hourly Earnings is significant for all ten maturities with a p-value smaller or equal to 0.016 (figure B.8 in appendix B.4.2). The impact is largest for maturities between two and six years, whereas a positive surprise of one standard deviation leads to a daily change of the interest rate of 0.4% to 0.5%.

The Non-Farm Payrolls indicator has an even stronger impact on the German bond market than the release of Average Hourly Earnings. The impact of a surprise is statistically significant with a p-value of 0.000 for all maturities (figure 3.6). Furthermore, the magnitude of the impact is very high. For maturities up to five years, a positive surprise of one standard deviation results in a reaction of interest rates between about 0.6% and 0.8%, whereas the maximum is at two years. For maturities between six and ten years, the impact declines from about 0.6% to 0.4%. The large reaction of the German bond market due to the release of Non-Farm Payrolls has two reasons. First, Non-Farm

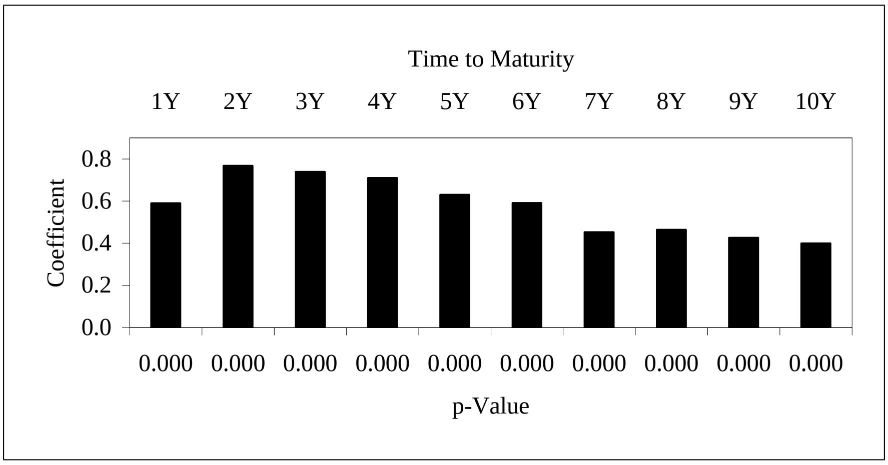

Figure 3.6: Announcement effect of Non-Farm Payrolls in the US on interest rates of German government bonds with maturities between one and ten years.

Payrolls is one of the most important indicators of the US economy and is therefore highly regarded on global financial markets. Second, the volatility of the releases of the Non-Farm Payroll indicator is very high and releases of the past months are often revised.

Another US indicator that influences the German bond market is the release of Durable Goods Orders, which only has a significant positive impact on bonds with maturities of three, four and five years (figure B.9 in appendix B.4.2). However, the magnitude of the influence is small (around 0.2%).

The impact of the release of Housing Permits is completely insignificant and the impact of the release of Housing Starts is only significant for a maturity of six years with a p-value of 0.100 and a coefficient of -0.18.[34] The housing market in the US gained its importance for the US-economy and for global financial markets only in the last part of the sample of this event study. That is the reason why the releases of Housing Starts and Housing Permits are insignificant.

A surprise in the release of the Industrial Production in the US significantly influences the German yield curve (at least at the ten percent level) for maturities of four, five and seven to ten years (figure B.10 in appendix B.4.2). The impact has a slightly larger magnitude at the medium part of the curve (around 0.3%) than at the long end (around 0.2%).

[34]Due to only one significant result, a figure is omitted.

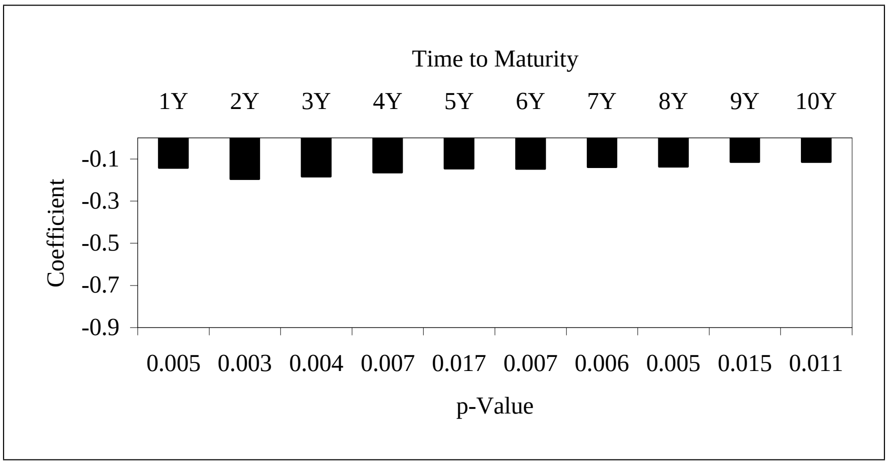

Figure 3.7: Announcement effect of Initial Jobless Claims in the US on interest rates of German government bonds with maturities between one and ten years.

The release of the Initial Claims for unemployment benefits is a weekly published indicator for the US labour market and has a significant impact on the whole maturity spectrum of the German yield curve (figure 3.7). Because of the weekly frequency of this indicator, the impact can be measured with a higher statistical confidence, as the number of observations is larger than for monthly and quarterly releases. A positive surprise in the Initial Claims, that is more people than expected claim initial unemployment benefits, indicates a slowing labour market and consequently an already slowing economy. So, market participants expect lower yields in the future, which is why the coefficient estimates are negative for the whole maturity spectrum. The level of significance of the estimated coefficients for this indicator is very high, whereas the magnitude is relatively small (between -0.1% and -0.2%).

Another indicator for real economic activity that is highly regarded in global financial markets is the indicator for Retail Sales in the US. The estimates of the coefficients have a positive sign, which is in line with economic theory (figure B.11 in appendix B.4.2). Higher retail sales indicate a higher private consumption which in turn stimulates the economy and yields higher interest rates. The impact is significant at the ten percent significance level on the whole maturity spectrum, whereas the magnitude of the impact is the largest for bonds with maturities of two, three and four years.

In addition to the set of indicators for real economic activity, the most important price indicators of the US are included in this event study, which have different effects on the German bond market. In contrast to the Consumer Price Index that does not have an impact on the bond market, the price index for Core Personal Consumption Expenditure has a strong and significant influence on the whole term structure (figure B.12 in appendix B.4.2). The estimated response of the bond market on a surprise of one standard deviation has a large magnitude (between 0.3% and 0.6%), whereas the impact is the largest on bonds with maturities of two and three years. The severe impact on the German bond market of the Core Personal Consumption Expenditure index can be explained by the fact that the Fed started to use this price index as the preferred inflation measure some years ago.

The headline rate of the Producer Price Index is insignificant, whereas the core rate of the Producer Price Index is significant for maturities of three, five and nine years (figure B.13 in appendix B.4.2). The magnitude of the impact is about 0.2%. This rather small impact in combination with only three significant maturities shows that the US Core Producer Price Index only slightly influences the German bond market.

The sentiment indicators for the US economy reveal important information on the future path of the US economy and are highly regarded by global financial market participants. For example, the Consumer Confidence of the Conference Board has a statistically significant (at the one percent level) impact of 0.2% to 0.3% on German interest rates of government bonds of all maturities (figure B.14 in appendix B.4.2).

The impact of the ISM Index for the manufacturing sector on the German bond market is as large as the impact of the Employment Report (figure 3.8). Even though the manufacturing sector is only a rather small part of the US economy nowadays, the manufacturing ISM Index is highly regarded in global financial markets, because it has a good forecasting ability for real economic activity in the US. Consequently, the ISM Index significantly influences interest rates over the maturity spectrum between one and ten years with a p-value of 0.000. The impact has always a larger magnitude than 0.4% and is the largest for maturities of four and five years (slightly below 0.7%). So, the size of the impact of the manufacturing ISM Index is larger than the impact of most of the other indicators in this event study.

Even though the ISM Index for the non-manufacturing sector covers a large part of the US economy, it has a smaller influence on financial markets than the manufacturing

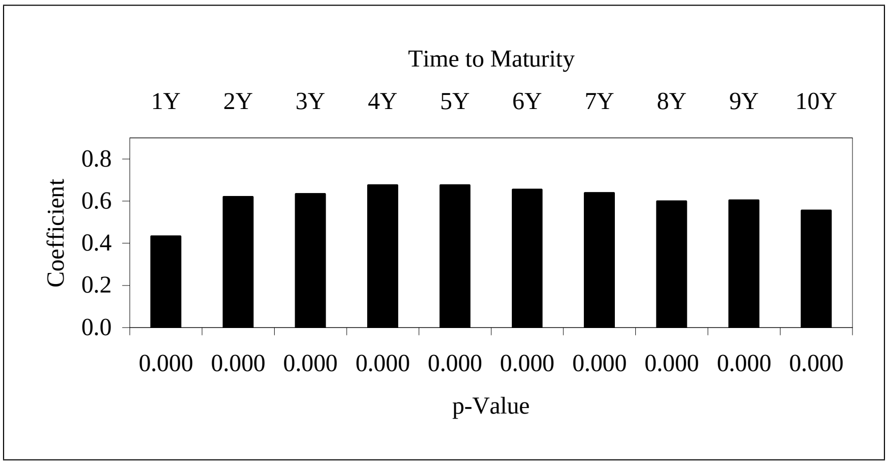

Figure 3.8: Announcement effect of the manufacturing ISM in the US on interest rates of German government bonds with maturities between one and ten years.

ISM Index (figure B.15 in appendix B.4.2). The non-manufacturing ISM Index only has a significant impact on bonds with maturities of at least four years, whereas the level of significance is lower than for the manufacturing ISM Index. Furthermore, the magnitude of the effect is smaller than of the manufacturing ISM Index.

Another sentiment indicator for the US economy that has a high influence on financial markets is the Chicago Purchasing Manager Index (figure B.16 in appendix B.4.2). Yields of German government bonds with maturities between two and five years increase around 0.4% due to a surprise of one standard deviation, whereas all other maturities increase around 0.3%, when the Chicago Purchasing Manager Index surprises on the upside.

3.7.2 Announcement Effects on the Slope and Curvature of the Yield Curve

In the last section, empirical results concerning the announcement effect of macroeconomic news on single points of the yield curve have been discussed. In this section, research that deals with announcement effects of macroeconomic news on the slope and the curvature of the yield curve is presented. There are several articles in the literature that research on the forecasting ability of the slope of the yield curve concerning inflation and output (section 4.2.1) as well as the stock market (section 4.2.4). For example, an upward sloping yield curve precedes an upswing in the economy and an inverse yield curve indicates a recession. Hence, positive macroeconomic news should increase the slope of the yield curve and vice versa.

In order to quantify the short term reaction of the slope of the yield curve to macroeconomic news, the dependent variable in this part of the event study is the daily percentage change of the slope of the yield curve $Slope_t$ at time t, which is defined as the difference between the yield of bonds with maturities of ten years and one year ($Slope_t = 10Y_t - 1Y_t$). The explanatory variables and the framework of the regression are the same as in the empirical analysis of the reaction of single maturities to macroeconomic news (equation 3.10). The coefficient β_{1i} in equation 3.12 quantifies the percentage change of the slope $Slope_t$ at time t due to a surprise S_{it} of one standard deviation in the release of indicator i at time t. The sum $\sum_{k=1}^{K} \beta_{k+1,i} S_{i_k,t}$ captures the effects of K simultaneously released indicators:

$$\frac{Slope_t - Slope_{t-1}}{Slope_t} \cdot 100 = \beta_0 + \beta_{1i} S_{it} + \sum_{k=1}^{K} \beta_{k+1,i} S_{i_k,t} + e_{it}. \tag{3.12}$$

Another aspect of this event study is to quantify the reaction of the curvature of the yield curve due to the release of macroeconomic news. The reaction of the curvature of the yield curve cannot be related to economic theory as easily as the reaction of the slope. Nevertheless, these results are reported and briefly discussed, because the curvature of the term structure of interest rates can be part of a trading strategy or investment decision. In order to measure the effect of macroeconomic surprises on the curvature of the yield curve, the dependent variable $Curvature_t$ at time t is defined as two times the interest rate of the medium part of the yield curve minus the sum of the short and long end of the yield curve: $Curvature_t = 2 \cdot 5Y_t - 1Y_t - 10Y_t$.[35] In equation 3.13, β_{1i} quantifies the impact of indicator i on the daily percentage change of the curvature of the yield curve $Curvature_t$ at time t, when the release of indicator i differs from the

[35] Whereas the applied definition of the slope variable $Slope_t$ is widely used in the literature, the curvature variable $Curvature_t$ is based on Diebold and Li (2005). To calculate the curvature of the term structure of interest rates, Diebold and Li use the three-month rate to approximate the short end of the yield curve, the two-year rate to approximate the medium part and the ten-year rate to approximate the long end: $Curvature_t = 2 \cdot 2Y_t - 3M_t - 10Y_t$.

	Indicator	Slope	Curvature
Germany	Unemployed	-	-65.932 / (0.017)
	Unemployment Rate	-	71.361 / (0.004)
	PPI, mom	-	115.768 / (0.023)
	PPI, yoy	-	-134.578 / (0.010)
	ZEW Index	-	79.977 / (0.068)
Eurozone	Current Account	-	-33.756 / (0.013)
	Retail Sales, mom	-	-22.419 / (0.021)
	Retail Sales, yoy	-	22.533 / (0.030)
USA	Average Hourly Earnings	-	8.552 / (0.090)
	Capacitiy Utilisation	2.227 / (0.064)	-
	Industrial Production	-2.058 / (0.079)	-
	Productivity, final	3.115 / (0.090)	-
	Unit Labour Costs	8.327 / (0.001)	-
	CPI	-1.341 / (0.046)	-
	CPI core	1.993 / (0.021)	-
	PPI core	4.385 / (0.008)	-
	ISM non-manufacturing	-	48.511 / (0.053)
	Chicago PMI	1.868 / (0.076)	-

Table 3.7: Results of the impact (percent) of German, European and US macroeconomic indicators on the slope and curvature of the German yield curve, which are significant at least at the ten percent level (p-values in parenthesis).

expectations by one standard deviation (S_{it}). The effects of K simultaneously released indicators are taken into account by $\sum_{k=1}^{K} \beta_{k+1,i} S_{i_k,t}$:

$$\frac{Curvature_t - Curvature_{t-1}}{Curvature_t} \cdot 100 = \beta_0 + \beta_{1i} S_{it} + \sum_{k=1}^{K} \beta_{k+1,i} S_{i_k,t} + e_{it}. \qquad (3.13)$$

The significant effects of German, European and US macroeconomic indicators on the slope and curvature of the German yield curve for government bonds are summarized in table 3.7.[36] None of the German indicators significantly influences the daily change of the slope of the yield curve. In contrast to that, a small number of German indicators has a significant impact on the curvature of the yield curve. Concerning the indicators for real economic activity, the estimate of the effect of the German number of people unemployed forces the curvature to decline by 65.93%, when the outcome of this indicator has been

[36]The whole set of results of the impact of the macroeconomic indicators on the slope and curvature of the term structure of interest rates can be found in appendix B.2.

underestimated by one standard deviation. The estimation result of the impact of the Unemployment Rate in Germany indicates an increase in the curvature due to a surprise of one standard deviation by 71.36%. Among the price indicators, the German Producer Price Index has a significant impact on the curvature. The impact of the month-on-month change of the producer prices on the curvature of the term structure is positive (115.77%), whereas the impact of the year-on-year change is negative (-134.58%), when the release has been underestimated by one standard deviation. Furthermore, a positive surprise in the sentiment indicator ZEW-Index causes the curvature of the German yield curve to react positively (79.98%).

None of the European macroeconomic indicators affects the slope of the German yield curve and only three affect the curvature. If the Current Account for the Eurozone is better than predicted, the curvature of the yield curve decreases significantly by 33.76%. The reaction of the curvature on surprises of the month-on-month change of European Retail Sales is negative (-22.42%), whereas the impact of the year-on-year change is positive (22.53%).

In contrast to German and European macroeconomic indicators, US macroeconomic indicators influence the slope of the German yield curve for government bonds. A positive surprise of real economic activity should increase the slope of the yield curve and vice versa. With varying size, the indicators for real economic activity Capacity Utilisation (2.23%), Productivity (3.12%) and Unit Labour Costs (8.33%) increase the slope of the yield curve, when the release surprises positively. The only indicator for real economic activity that reduces the slope of the yield curve is the release of Industrial Production (-2.06%) and therefore does not confirm economic theory. The reason might be that Industrial Production is a contemporary indicator for real economic activity. In contrast to that, a leading indicator, for example the sentiment indicator Chicago Purchasing Manager Index, influences investors' expectations of long term interest rates (1.87%). The US price indicators Core Consumer Price Index (1.99%) and Core Producer Price Index (4.39%) increase the slope of the yield curve. The headline Consumer Price Index decreases the slope (-1.34%).

The curvature of the yield curve is positively influenced by the release of the US indicator for real economic activity Average Hourly Earnings (8.55%) and by the release of the sentiment indicator non-manufacturing ISM (48.51%). Accordingly, these two macroeconomic indicators enhance the curvature of the yield curve of German government bonds because of an increase of the sum of the differences between the short end and the medium part and between the long end and the medium part of the yield curve.

3.7.3 Summary of Results

This empirical event study confirms the significant impact of a large set of German, European and US macroeconomic indicators on the yield curve of German government bonds, whereas the sign and size of the impact of the several macroeconomic indicators varies. This result is similar to Balduzzi, Elton and Green (2001) who find that the null hypothesis of equal effects in terms of size and magnitude of the release of a macroeconomic indicator on different maturities along the yield curve can be strongly rejected.

The first part of this event study quantifies the announcement effect of a single indicator on bonds with different maturities between one and ten years. The sign of most of the significant announcement effects is in line with economic theory of a positive correlation between real economic activity, prices and sentiment indicators with the overall level of interest rates. The release of a substantial number of US indicators has a larger impact on yields of German government bonds than most of the German and European indicators. For example, the releases of Non-Farm Payrolls and the manufacturing ISM in the US have very strong impacts on the German bond market. The only German or European macroeconomic indicators which have a comparable effect are the sentiment indicators Ifo-Index and European Sentiment Indicator.

Significant German indicators have the largest impact on bonds with maturities between two and four years, whereas the maximum is at a maturity of two years. The reason is that the release of macroeconomic news mainly affects the short term expectations of market participants concerning the future path of the economy. Consequently, as the yield of a long term bond is based on long term expectations of market participants, the reaction of long term bonds tends to be smaller than of short term bonds. In addition to that, monetary policy enhances the effect of the release of macroeconomic news on bonds with a time to maturity of two years, because the yield of a two-year bond depends on the expected target rate of the central bank for the short term money market rate over the next two years. As the decision of the central bank is influenced by current releases of macroeconomic indicators, monetary policy is another reason why macroeconomic news has the largest impact on bonds with a maturity of two years. This result is contrary to Balduzzi, Elton and Green (2001) who find that the impact of the surprise component on the yield of government bonds rises with the maturity of the bond. They argue that bonds with a longer maturity have a higher duration and consequently their price movements are more volatile than that of short term bonds.

The second part of this event study quantifies the announcement effects of macroeconomic news on the slope and curvature of the yield curve of German government bonds. Both the slope and the curvature significantly react to a number of macroeconomic indicators from Germany, the Eurozone and the US. Whereas German and European indicators do not significantly influence the slope of the yield curve, eight US indicators (of the US indicators that are included in this event study) have a significant impact. Among these eight significant indicators, six confirm that a positive surprise of an indicator for real activity, price indicator or sentiment indicator causes the slope of the yield curve to increase. In contrast to US macroeconomic indicators that significantly affect single yields and the slope of the yield curve, German and European indicators only significantly affect the curvature. Five German indicators, three European indicators and only two US indicators have a significant impact on the curvature.

The reaction of the slope and curvature of the yield curve is implicitly analysed in the first part of this event study, where the announcement effects on single yields of bonds with maturities between one and ten years are quantified. Hence, the ratio of the coefficient estimates of the various maturities also roughly indicates the reaction of the slope and curvature. For example, the impact of the ZEW-Index shows that the reaction of the five-year yield is larger than the reaction of yields with a maturity of one and ten years. This implies an increase in the curvature of the yield curve.

In general, the empirical results show that a German, European or US macroeconomic indicator which has a significant impact on single yields of German government bonds does not necessarily have a significant impact on the slope or curvature of the

German yield curve, too. For example, the Ifo-Index, Non-Farm payrolls and the manufacturing ISM, which have a very large impact on single yields of German government bonds, do neither significantly affect the slope nor the curvature. The reason is that these market movers have an effect of statistical equal size on all yields.

As the analysts' forecasts are biased for the Ifo-Index and for the Non-Farm Payrolls and unbiased for the manufacturing ISM, there might be no clear relationship between the forecast error of the analysts' forecasts for an indicator and the magnitude of the announcement effect of this indicator on the German yield curve of government bonds.

3.8 Conclusion

It is widely accepted that the release of macroeconomic news significantly affects financial markets. Event studies on the reaction of financial markets are not only of interest for financial market participants but also for central bankers, because the market reaction due to macroeconomic news provides additional information of the market participants' expectations concerning the future inflation (and real activity). Most of the literature concentrates on price changes, trading volume or volatility due to the release of macroeconomic news, whereas this empirical event study focuses on price changes. A distinctive characteristic of this event study is that the reactions of bond yields with maturities between one and ten years are separately quantified. Even though the results for a certain macroeconomic indicator may differ from other findings in the literature, the fact that macroeconomic news affects government bond markets is validated. The hypothesis that some macroeconomic indicators affect the slope and curvature cannot be rejected and therefore these variables should be included in an event study.[37]

In further research it might be interesting to include the trading volume. For example, D'Souza and Gaa (2004) state the importance of deep market liquidity when shocks occur in the financial system. Consequently, event studies which consider the liquidity provide aspects of financial market regulation and of financial stability. Another focus

[37] The level of the yield curve corresponds to the First Principal Component of the yield curve, whereas the slope and curvature correspond to the Second and Third Principal Component (section 2.3).

of further research could be to distinguish between the impact of positive and negative surprises of macroeconomic news on the bond market.

Not all relevant information that causes a price change of government bonds can be captured in an empirical event study. For example, it is difficult to include the current market sentiment, even though it might be able to partially explain the daily change of government bond yields when macroeconomic information is released. The reason is that the current market sentiment might be represented by historical price changes, which cannot be included due to the Efficient Market Hypothesis. If past returns had explanatory power for current price changes, this would imply that publicly available information is not fully included in current market prices.

Chapter 4

The Relative Attractiveness of the Asset Classes during the Business Cycle

The tale of the stockbroker who visits the countryside and sees a shepherd with his flock: "I'll bet you one of your sheep that I can tell you how many are in your field," he says. The shepherd agrees, and the broker responds "320". "Amazing, you win," replies the shepherd. The broker takes an animal and begins to walk away when the shepherd suddenly shouts: "Wait, I'll bet you double or nothing I can tell what your profession is." The broker agrees. "You're a stockbroker," says the shepherd. The broker stunned, says "How did you know?" The shepherd replies: "Let go of my dog and I'll explain."

— Dimson, Marsh and Staunton (2002)

4.1 Asset Allocation and the Business Cycle

Dimson, Marsh and Staunton (2002) use the tale of the stockbroker who visits the countryside to state the necessity of a comprehensive view when dealing with asset prices, because numerous factors such as "economic, political, social, environmental and business factors" influence financial markets. Nevertheless, some financial professionals tend to dismiss some of these relevant factors for financial markets – like the stockbroker in the tale above who obviously did not consider all necessary information to differentiate between a sheep and a dog.

The analysis in the previous chapters shows that macroeconomic information influences the bond market. In the second chapter, the macroeconomic drivers of the term structure of interest rates are theoretically motivated and empirically tested. Whereas the second chapter has a medium term perspective, the third chapter has a short term perspective and presents an event study of announcement effects of the release of macroeconomic indicators on the term structure of interest rates. This chapter presents an empirical analysis which considers all main financial markets and the real economy simultaneously. This interdependence is analysed by a VAR analysis of the main asset classes and the business cycle of the real economy. This analysis enables investment decisions based on the expected path of the economy and its linkages with the main financial markets. The forecasts of asset prices are based on the comovement between the real economy and financial markets. Consequently, expectations of the real economy determine expectations of asset prices. The approach to forecast asset prices in dependence of the real economy is called Top-Down approach which is often applied in the financial services industry.

Asset Allocation is the process of splitting an amount of money to be invested in financial markets across various asset classes. Whereas Strategic Asset Allocation has a medium and long term perspective, Tactical Asset Allocation has a short term perspective. The optimal asset mix has to be consistent with the investor's risk aversion, return expectations and other preferences. A systematic approach to Asset Allocation should integrate all these aspects (Sharpe (1988)). Therefore, the constituents of the portfolio are chosen in dependence of their expected returns and their correlations to other assets in the portfolio, i.e. of the relative attractiveness of the asset classes. Hence, Asset Allocation can be seen as the main determinant of the performance of the portfolio (Lee (2000)). Clarke (1988) states that a disciplined rather than an ad hoc approach to Asset Allocation is more important for the long term performance of the portfolio than the selection of the portfolio manager or the single security.[1] The main focus of Asset Allocation is to forecast the prices in financial markets (Gast (1998)), because they constitute the expected return of the portfolio.

One of the key characteristics of globalisation is the significant increase in international capital flows. Consequently, investors choose the constituents of their portfolio from a large universe of domestic and international assets (Global Asset Allocation). Hence, it is necessary to gauge the attractiveness of an asset relative to other domestic and international asset classes as well as relative to the same asset class in another country. For example, in the context of stocks, the comparison of price-earnings ratios or earning yields between countries is not an appropriate measure of the relative attractiveness of stocks in different countries, because it is necessary to subtract the cash or bond yield from the earnings yield in the equity market (Arnott and Henriksson (1988)). This equity risk premium yields a direct and objective measure of the relative attractiveness of a stock within and between countries, because it accounts for the varying economic risks between different countries. According to Arnott and Henriksson, this procedure can also be applied to compare other asset classes than stocks. Due to the fact that this empirical analysis tries to compare the relative attractiveness of the main asset classes, the interest rates and returns are adjusted by the short term money market rate in order to make them comparable.

The final return of a portfolio of international investments is determined by the exchange rate.[2] A positive future development of the exchange rate can overcompensate a negative rate of return of the initial investment abroad and vice versa. Hence, the

[1] Nevertheless, there is a large amount of research that deals with market timing and security selection and only a small amount of research that deals with the investment decision between stocks, bonds and cash (Bange, Khang and Miller (2008)).

[2] The return of an international portfolio is only independent of exchange rate movements if the portfolio is completely hedged against movements in the exchange rate. The cost of this protection lowers the return of the portfolio.

foreign exchange rate is a second source of risk in addition to the initial risk of the uncertain future market price of the security (Gibson (1991)). However, the empirical analysis of this chapter covers the linkages between Euro denominated assets of German financial markets and the real economy in Germany.[3] As investors have a home bias when allocating their assets, the concept of Global Asset Allocation is not applied by all European investors. Therefore, this analysis focuses on the European financial market which has a large capitalisation.

The investment horizon has significant implications for the optimal Asset Allocation. Long term returns on financial markets have the property that the distribution of compounded annual rates of returns tightens as the sample period increases. Contrary, the distribution of the wealth at the end of the investment period broadens (Siegel and Ibbotson (1988)). A comprehensive overview of long term returns on financial markets is given by Dimson, Marsh and Staunton (2002). They present historical time series of returns of stocks, bills and bonds over a time horizon of up to 101 years for a large number of countries.

The analysis of this chapter is divided into the following sections. First, Asset Allocation is described in section 4.1 which relates the asset mix in a portfolio to the expected return of each asset class. Section 4.2 discusses the linkages between the prices in the main financial markets and the state of the real economy in the business cycle. The asset classes that are considered in the empirical analysis and the constructed real-time output gap are described in section 4.3. The VAR analysis between the real economy and the main financial markets can be found in section 4.4 and its results in section 4.5. Section 4.6 discusses the implications of the results for Asset Allocation.

[3]The state of the German economy, the prices in German financial markets and their linkages might depend on the exchange rate of the Euro, because the value of the currency determines the attractiveness of all domestic assets to foreign investors. However, these effects are omitted in the relative comparison of Euro denominated assets in this chapter, because it is assumed that the exchange rate of the Euro has a similar effect on all of them.

4.1.1 Strategic Asset Allocation

Strategic Asset Allocation determines the basic characteristics of the portfolio in terms of risk and expected return, because it defines the long term asset mix of the investment across the several asset classes. The ratio of the asset classes has to be checked on a frequent basis, because the investor's expectations of the economic situation and future returns might change or the movements of prices on financial markets might change the ratio of the asset classes in the portfolio. Consequently, the portfolio mix is no longer optimal and has to be rebalanced.

Strategic Asset Allocation has a significant influence on the performance of the portfolio and depends on the preferences of the investor.[4] These preferences are different for private and institutional investors in terms of risk aversion, expected (minimum) return and investment horizon. Two concepts which are important for Strategic Asset Allocation are Portfolio Insurance and Asset Liability Management.[5]

The concept of Portfolio Insurance keeps the value of a portfolio above a chosen floor value, because it changes the return distribution and makes large losses unlikely. As a consequence, the return of the portfolio is lower than the market return when market returns are positive, because the protection of the portfolio generates costs for the investor. However, when financial markets suffer from losses, Portfolio Insurance can heighten the speed and extent of the market decline. The reason is that the exposure of a portfolio to risky assets is reduced by selling these risky assets. As a consequence, Portfolio Insurance further enhances the market volatility when financial markets are already stressed (Gastineau (1988)).

A common approach to Portfolio Insurance is the Option-Based approach where call or put options are included in the portfolio (Sharpe (1988)). The strike price of an option is the floor level for the value of the portfolio at the end of the investment horizon. In a Time-Variant Option-Based Portfolio Insurance strategy, the amount of money invested in the risky asset positively depends on the value of the portfolio's assets relative to

[4]That is why the identification of the preferences of the investor has major implications in the Asset Allocation approach (Gast (1998)).

[5]All concepts of Strategic Asset Allocation are based on investment decisions which do not rely on market timing. In contrast to that, Tactical Asset Allocation tries to benefit from short term deviations from the long term asset mix (section 4.1.2).

the floor (cushion) and positively on the remaining time until the expiration date of the option. However, this concept is inappropriate for very long investment horizons, because if the time to maturity of the investment is very long, the risk aversion of an investor does not change in the short term. Hence, there is the Time-Invariant Option-Based Portfolio Insurance strategy, where the amount of money invested in the risky asset is equal to the value of the portfolio's assets relative to the floor times a constant factor greater than one.[6]

Another concept of Strategic Asset Allocation is Asset Liability Management, which optimises the matching of the future value of assets and liabilities. For example, pension funds follow the concept of Asset Liability Management in order to be able to pay the future pension benefits to their clients. As the investment horizon of pension funds is long term and the real value of pension benefits is important for pensioners, inflation has to be taken into account. The reason is that a higher rate of inflation has a negative effect on real pension benefits, because it reduces the real return of a long term bond portfolio. Empirically, this effect is larger than the positive effect of a higher rate of inflation on nominal wages and therefore on nominal pension benefits (Goodman and Marshall (1988)). That is why pension funds try to avoid the negative effects of inflation on their portfolio. Accordingly, the Strategic Asset Allocation of investors, which is based on their preferences, has feedback effects with the macroeconomy in the long term.

In general, investors who assume that the Efficient Market Hypothesis (section 3.1) holds at any time and that asset prices are not predictable in the short term do not change the portfolio due to short term movements in financial markets (passive investment approach). Therefore, they invest in a portfolio with a constant asset mix given by the Strategic Asset Allocation (Statman (2000)). In contrast to that, investors who assume that financial markets can be temporarily inefficient or predictable try to enhance the return of their portfolio by Tactical Asset Allocation (active investment approach).[7] In this case, if the expectations of the future path of the real economy change, the expec-

[6]The concept of the Time-Invariant Option-Based Portfolio Insurance is also known as Constant Proportion Portfolio Insurance (CPPI).

[7]The concept of Tactical Asset Allocation is similar to the concept of Market Timing, where the constituents of the portfolio are changed frequently.

tations of future asset prices change which in turn yields an adjustment of the asset mix of the portfolio. Therefore, correct forecasts of financial markets and the real economy play a major role in Tactical Asset Allocation.

4.1.2 Tactical Asset Allocation

In contrast to Strategic Asset Allocation, Tactical Asset Allocation has a short and medium term horizon (Fabozzi (1999)). Usually, Tactical Asset Allocation covers the time period between three and 18 months. Brennan, Schwartz and Lagnado (1997) state that Tactical Asset Allocation was one of the first applications of the Markowitz portfolio theory in order to optimise the split between stocks, bonds and money. In order to increase the return of the portfolio, Tactical Asset Allocation temporarily deviates from the long term asset mix of the portfolio given by the Strategic Asset Allocation which determines the benchmark return. So, it is possible to avoid extreme market situations by increasing the holding of risk-free assets.[8] The application of Tactical Asset Allocation assumes that financial markets are not perfectly efficient, that is the Efficient Market Hypothesis can be temporarily rejected (von Metzler (1995)). Under this assumption, investors are able to generate a return higher than the market return due to their research and experience.[9]

In practice, the return of an actively managed portfolio (Tactical Asset Allocation) is compared with the return of the passive benchmark portfolio (Strategic Asset Allocation). The difference between the return of the actively and passively managed portfolio is alpha (Lee (2000)). Tactical Asset Allocation tries to generate a stable and positive alpha. Therefore, fund managers can signal their investment skills by a low volatility of alpha (Rey (2004)). The process of Tactical Asset Allocation tries to predict the relative returns of the various assets. In an ex ante perspective, the nominal returns of the various asset classes differ in terms of uncertainty: the nominal return of a short

[8] Due to the fact that interest rates on the money market are determined on the interbank market and banks can suffer from default, money market investments are risky (section 2.5).

[9] As a final step in the investment process, it is necessary to pick the single asset in an asset class chosen by the Tactical Asset Allocation. This selection of a single security is left aside in this analysis, because it is neither driven by macroeconomic factors nor by the comovement of the macroeconomy and financial markets.

term investment in the money market and the yield to maturity of a long term bond are known, whereas the future nominal return of an investment in equities is unknown and has to be estimated (Arnott and Hendriksson (1988)).

There are several approaches to Tactical Asset Allocation. One approach to Tactical Asset Allocation is to assume that returns on financial markets are mean-reverting. For example, Hartpence and Sikorav (1996) deal with investors who assume that prices in financial markets have an equilibrium or fair price. Accordingly, investors expect the price to return to its fair value, if the actual asset price temporarily deviates from its fair value. These short term expectations for the price of the asset are used in the Tactical Asset Allocation by changing the constituents of the portfolio in order to benefit from the temporal deviation.

Another approach to Tactical Asset Allocation is a quantitative trend following model (Faber (2006)), which assumes that the market has a momentum (i.e. a serial correlation). Kahneman and Tversky (1979)[10] explain the success of trend following models (momentum trading) by the prospect theory of behavioural finance. Accordingly, investors tend to make irrational decisions in terms of sticking too long to assets that are losing value and selling assets too early that are gaining value. Faber proposes a quantitative trading strategy which signals to buy if the monthly price is larger than its ten-month moving average. Similar, the strategy signals to sell if the monthly price is smaller than its ten-month moving average and to hold cash. This quantitative trading strategy outperforms the S&P 500 during the long term period between 1900 and 2005. However, during the short term period between 1990 and 2005, the S&P 500 index has a higher return than the return generated by the momentum model. The reason is that the quantitative strategy has to be applied during a complete business cycle in order to guarantee that the underperformance of the strategy during a bull market is overcompensated during a bear market

Further common approaches to Tactical Asset Allocation are Valuation approaches and Cyclical approaches (Fabozzi (1999)). Investors who use a Valuation approach try to buy the asset at a low price and sell it a high price. The Valuation approach implies

[10] Faber (2006) quotes Kahneman, D. and A. Tversky, 1979, Prospect Theory: An Analysis of Decision under Risk, Econometrica, 47(2), 263-292.

that the various asset classes are compared to find the asset class that is currently undervalued. The Cyclical approach assumes that financial markets and the real economy are strongly related. An example for the Cyclical approach is the Top-Down approach that is based on the bidirectional effects between the real economy and financial markets (section 4.1.3).

DuBois (1992) distinguishes between Fact-Based and Forecast-Based approaches to Tactical Asset Allocation. The Fact-Based approach uses only currently available information, whereas a Quantitative Fact-Based approach is systematic and disciplined. The Forecast-Based approach additionally uses forecasts of financial and economic variables. Consequently, Forecast-Based investment decisions are uncertain, because it is difficult to forecast asset returns with other financial or economic variables. As the approach to Tactical Asset Allocation considers the long term as a sequence of short term periods, accurate forecasts in the short term result in a high performance of the portfolio in the short and in the long term. However, even if the forecasts of financial or economic variables contain a small forecast error, the return of the portfolio is higher than the benchmark return.[11]

Another approach to Tactical Asset Allocation is the Bottom-Up approach. The Bottom-Up approach determines the optimal asset mix of the portfolio by focusing only on the characteristics of a single security. When the Bottom-Up approach makes use of forecasts for future earnings or dividend growth, it is a Forecast-Based approach. The direct counterpart to the Bottom-Up approach is the Top-Down approach, which is discussed in the next section.

4.1.3 Top-Down Approach

The Top-Down approach is an often applied concept in Tactical Asset Allocation and is an active approach. It is based on the strong cyclical comovement of the business cycle and financial markets. A change of real economic activity alters the relative at-

[11] Furthermore, DuBois (1992) describes the Sentiment Concept of Tactical Asset Allocation where the sentiment of investors is measured and taken into account as well as the Technical Concept of Tactical Asset Allocation where past linkages of market prices or volumes are considered to forecast future asset prices.

tractiveness of the main asset classes, because the business cycle has a large influence on the investors' expectations of future returns of the main asset classes. The Top-Down approach temporarily deviates from the long term mix of the portfolio in order to increase the return of the portfolio, whereas the asset mix is determined by the state of the business cycle. The correlation between the business cycle and financial markets might be enhanced by the overreaction of financial markets. That is why investors often base their decisions on expectations of the financial market or of the economy that are not consensus among investors in order to benefit from the strong reaction of financial markets due to changes in the real economy (Sharpe (1988)). Furthermore, the Top-Down approach assumes strong linkages between the main asset classes. As a consequence, the observation of one of these markets gives insights into the likely future path of another market (DuBois (1992)).

The Top-Down approach is very similar to the concept of Business Cycle Anticipation (Diermeier (1988)). Accordingly, the investor assumes that the real economy follows the pattern of a typical business cycle: an economic expansion is followed by a slowdown, contraction, recovery and again an expansion. Hence, the investor tries to forecast the future path of financial markets based on the expected future state of the business cycle. The investor assumes that the state of the business cycle influences corporate profits and interest rates which in turn have a large impact on the prices of stocks, bonds and other securities. If the investor is able to forecast economic variables, she is also able to predict the direction and magnitude of changes of prices in financial markets. Even if the lead and lag relationships between the business cycle and financial markets may be variable or temporarily nonexistent, this cyclical relationship should be considered in Tactical Asset Allocation, because small fluctuations in the economy can have significant effects on financial markets (Cullity and Moore (1988)). Consequently, the most important determinant of expected returns in the Top-Down approach is the macroeconomy.

To apply the Top-Down approach in the process of Tactical Asset Allocation for fund management, it is necessary to obtain timely information of the current state of the economy and to have reasonable expectations of the future path of the economy. In addition to that, the link between the business cycle and the relative attractiveness of the returns of the main asset classes has to be predicted in a correct manner. The characteristics of the relationships that have been observed in the past should be valid in the future and the expectations regarding the timing of the relative attractiveness of the asset classes has to be correct, too. Clarke and Statman (1992) present empirical results for a Tactical Asset Allocation between the two asset classes stocks and cash, whereas the asset mix depends on a leading indicator for economic activity. Based on 40,000 monthly return simulations with a changing asset mix once a month, they state that Tactical Asset Allocation does not only increase returns but also lowers the variance of the returns. However, the higher returns are significantly reduced by transaction costs in reality.[12]

4.1.3.1 Comovement of the Business Cycle and Asset Classes

The Top-Down approach makes use of empirically validated stylised facts of the relationship between the returns of different assets and the business cycle. Foremost, this approach tries to forecast the returns of stocks, bonds and money during the different phases of the business cycle. The forecast of the future relative attractiveness of the main asset classes is based on the forecast of real economic activity. The stylised facts concerning the relationship between the state of the business cycle and the returns of stocks, bonds and money are summarised in table 4.1 and figure 4.1 according to DuBois (1992), Gast (1998) and von Metzler (1995).[13]

According to the Top-Down approach, the returns of assets change with the state of the business cycle. The returns of stocks and the yield of short and long term fixed income assets tend to be positively correlated with the real economy. The returns of stocks are driven by real economic activity, because economic growth has an impact on corporate earnings and consequently on stock prices and dividends. The overall level of interest rates is driven by real economic activity, because economic growth has an

[12]These transaction costs are not explicitly considered in this empirical analysis.

[13]In figure 4.1, an increase in the return of the stock market and in the short term interest rate enhances the relative attractiveness of the asset classes in the short term. As the ten-year interest rate is the yield to maturity of a ten-year government bond, the relative attractiveness of government bonds in the short term is negatively correlated with the ten-year interest rate. Therefore, a decrease in the ten-year interest rate enhances the relative attractiveness of government bonds.

Phase in the business cycle	after trough to mid of upswing	mid of upswing to peak	after peak to mid of downswing	mid of downswing to trough
Most attractive	stocks	money	bonds	stocks
Medium attractive	money	stocks	money	bonds
Least attractive	bonds	bonds	stocks	money

Table 4.1: Relative attractiveness of the main asset classes during the business cycle. Source: von Metzler (1995).

impact on the monetary policy of the central bank, on the demand for money and credit as well as on the price level.

At the beginning of an upswing in the business cycle ([4;1] in figure 4.1), stocks significantly increase in value and are the most attractive asset class (Gast (1998)). The reason is that market participants have positive expectations of future corporate earnings during the cyclical expansion of the economy. In this early phase of the economic recovery, short and long term interest rates are low and cause excess liquidity. This excess liquidity is an additional factor for a higher demand for stocks and higher prices on stock markets. The level of the short term interest rate which is determined by the central bank is low, because there is no upward pressure on the price level and the monetary authority tries to support the economy with liquidity. However, the monetary policy is not as accommodative as during a downswing of the economy and therefore the asset class money is medium attractive. The low demand for loans and capital further depresses the overall level of interest rates, which makes bonds the least attractive asset class. As the economic recovery proceeds, the general level of interest rates increases because of higher inflation expectations and a higher expectation of the demand for credit. The increase in interest rates does not necessarily result in a loss of attractiveness of stocks, because the higher level of interest rates is due to a higher price level which indicates a higher pricing power and a higher profitability of firms.

In the second phase of the economic recovery ([1;2] in figure 4.1), the strong real economic activity increases the demand for investments and the output gap is closing. The output gap is the difference between actual output growth and potential output growth of the economy.[14] These developments increase the demand for credit which

[14]See section 4.3.2 for a description of the output gap in this analysis.

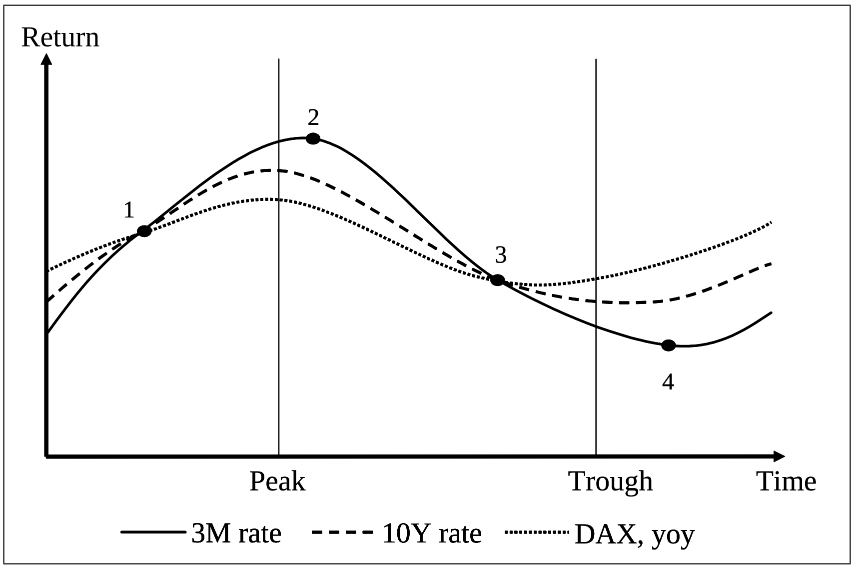

Figure 4.1: Relative attractiveness of main asset classes during the business cycle. Source: von Metzler (1995).

causes upward pressure on long term interest rates. Hence, long term bonds are the least appealing investment alternative. As the price pressure is increasing due to the narrowing output gap, the central bank further increases the short term interest rate in order to guarantee price stability. Consequently, cash is the most attractive asset class. The demand for stocks and their prices decline further, because market participants already expect the following downswing of the economy. Hence, the level of the stock market reaches its maximum before the real economy is peaking.

Shortly after the peak in the business cycle and during the downswing ([2;3] in figure 4.1), interest rates of all maturities tend to peak, because the central bank keeps the short term interest rate at a restrictive level as the inflationary pressure persists temporarily. When the upswing gains momentum, the central bank starts to reduce the short term interest rate so that money is the medium attractive asset class. During this stage, bonds are the most attractive asset class due to the decrease in long term interest rates. The negative outlook for the economy makes stocks the least attractive asset class.

In the last part of the cyclical downswing and before the economy reaches its trough ([3;4] in figure 4.1), the central bank holds the short term interest rate at a very low level in order to stimulate economic growth. Consequently, money market instruments are least attractive. The anticipation of the following upswing results in a significant and fast increase in the stock market so that stocks are the most attractive asset class. As market participants expect the decline of the long term interest rate to end in the near future, bonds are medium attractive. Similar to the upper turning point of the business cycle, interest rates turn shortly after the trough of the economy.

The stylised facts above are validated by the empirical study of Cullity and Moore (1988). They state that a severe decline in stock prices in the US usually precedes a recession and that increasing stock prices precede a following expansion. They further observe that the bond market is also strongly influenced by the business cycle. So, interest rates for corporate, municipal and government bonds increase during an upswing and decline during a downswing. To sum up, a higher real economic activity is good for stock prices and bad for bond prices and vice versa.[15]

When implementing the Top-Down approach, several adjustments of the asset mix are required as the current or expected economic situation changes frequently. Hence, the timing of these investment decision is the more important the higher the volatility of the asset, because securities with a high volatility have a high ratio of risk and return in the short term. Contrary, assets with a low volatility have a lower ratio in the short term what makes the timing of the investment decision less important (Bahlmann, Hansul and Brendel (2007)). Another practical aspect of the Top-Down approach is that the stylised pattern of various asset returns during the business cycle may differ from the actual return series as each business cycle has its own characteristics and effects on financial markets (DuBois (1992)). In addition to that, the usual course of the business cycle is influenced by the pattern of fiscal and monetary policy which changes over time (Cullity and Moore (1988)).

[15] In addition to the empirical validation of the stylised facts, Cullity and Moore (1988) state that the business cycle influences the volume of new issues on the primary market for stocks and bonds. The reason is that firms tend to issue stocks rather than bonds during an expansionary phase, when stock prices are increasing and bond prices are declining. Analogous, firms tend to issue bonds in a downswing of the economy. The impact of real economic activity on the supply of returns on financial markets is discussed in more detail in section 4.3.2.

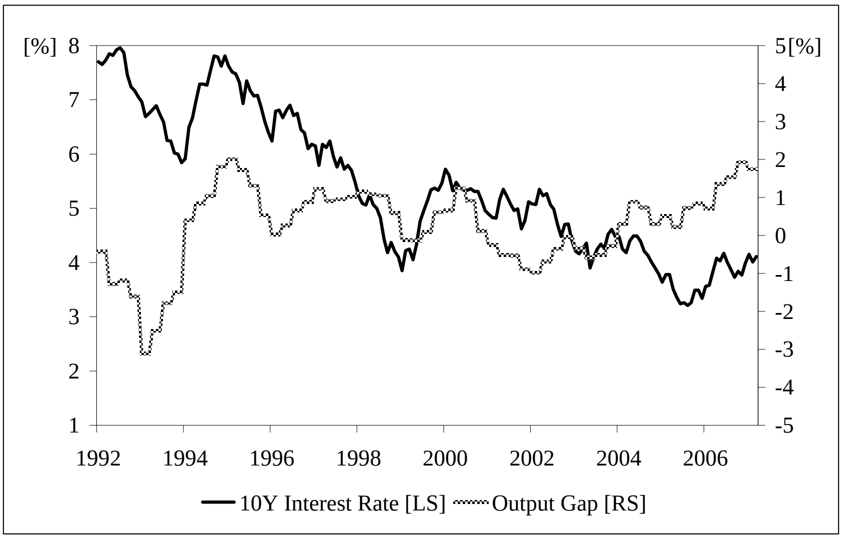

Figure 4.2: German output gap and ten-year interest rate of government bonds.

4.1.3.2 Descriptive Analysis

In this section, the stylised facts of the Top-Down approach are empirically analysed with actual data of asset returns and the state of the economy. Figures 4.2 to 4.5 verify the stylised facts of the section above, whereas the year-on-year return of stocks, the short term interest rate and the long term interest rate of government bonds show pro-cyclical movements over substantial periods of the sample (January 1992 to March 2007).

Figure 4.2 shows the long term interest rate of German government bonds with a time to maturity of ten years and the business cycle. The state of the real economy is represented by the output gap, whereas a positive value of the output gap signals a growth of the economy above its potential growth and vice versa. The level of the long term interest rate has a pro-cyclical behaviour, what is in line with the stylised facts. The German long term interest rate has a downward trend between 1992 and 2007. Since this pattern of the long term interest rate has also been observed in other financial markets than Germany, there is a lively discussion of the reasons for the low level of long term interest rates in the recent past (Greenspan's conundrum, section 1.2). Consequently, the German long term interest rate is adjusted by this deterministic downward trend in figure 4.3. The business cycle and the detrended long term interest rate also show cyclical comovements, whereas the two series have the same upward and

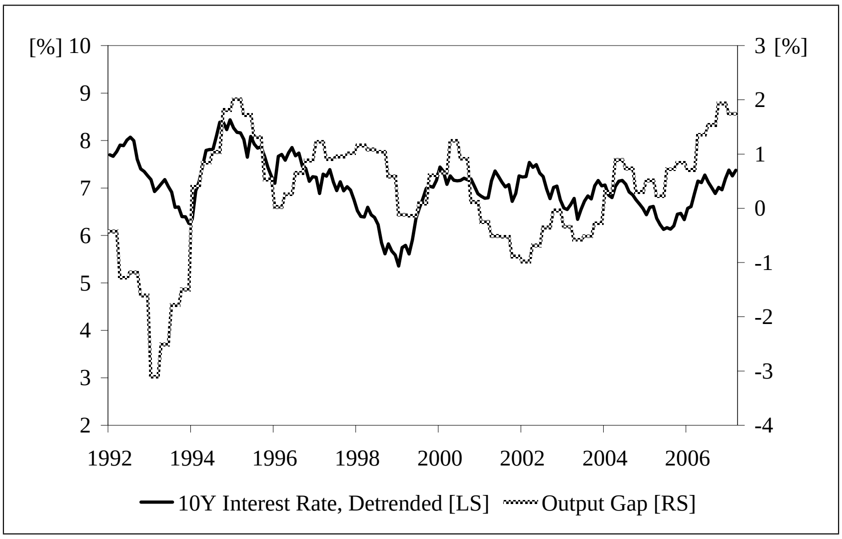

Figure 4.3: German output gap and detrended interest rate of ten-year government bonds.

downward movements in most parts of the sample. At the end of the sample, both have an upward trend.

The behaviour of the three-month money market rate and the output gap is shown in figure 4.4 which is in line with the Taylor rule for monetary policy (section 2.4.3). According to the Taylor rule, the central bank raises the short term interest rate in times when the economy is expanding above its potential growth and reduces short term interest rates when the economy is decreasing. The latter can be observed at the beginning of the sample, when the output gap is negative and the short term interest rate decreases from nearly 10% to below 6%.

In figure 4.5, the year-on-year growth rate of the main German stock index DAX and the output gap also show comovements. Both series are moving closely together over a substantial period of the sample. For example, the peaks of the year-on-year returns of the German stock market in the years 2000 and 2004 precede the following peaks of the output gap. Nevertheless, the stylised fact that the stock market is leading the economy cannot be validated over the whole sample, because sometimes the output gap turns before the stock market (for example in 1993 and 1997).

To sum up, the stylised facts of strong linkages between the real economy and financial markets can be validated for Germany. As the Top-Down approach is based on the expectations of the economy and returns on financial markets, it is a Forecast-Based

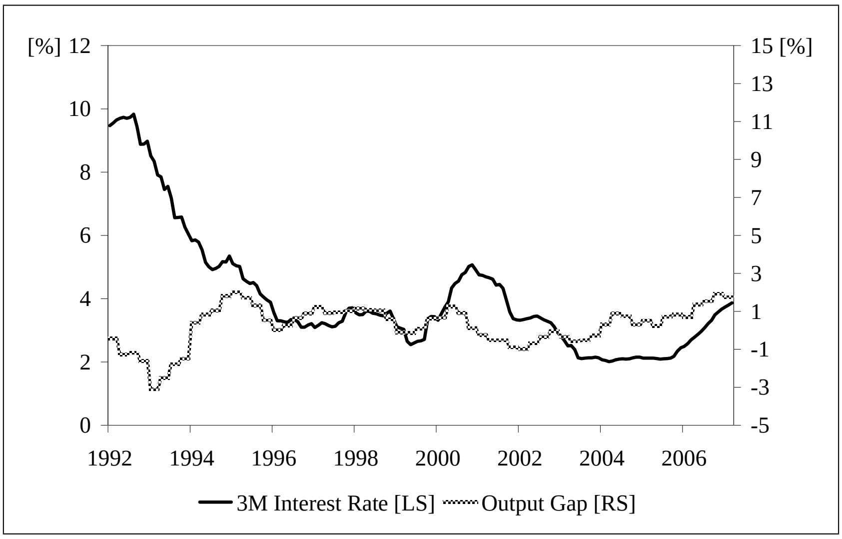

Figure 4.4: German output gap and three-month money market rate.

approach (DuBois (1992)). Therefore, the quality of the forecasts of financial markets depends on the quality of the forecasts of the real economy. A difficulty of the Top-Down approach is to determine the exact phase of the real economy in the business cycle, because the actual business cycle may differ from the typical pattern. Hence, it is not easy to determine peaks, troughs and turning points in the actual business cycle (Bahlmann, Hansul and Brendel (2007)). This difficulty intensifies when implementing the Top-Down approach in Global Asset Allocation, because the investor has to forecast the path of various economies (von Metzler (1995)).

4.2 Financial Markets and the Economy

As there are various links between financial markets and the business cycle, this section enlightens the two-sided relationships between the main asset classes and the macroeconomy described in the previous sections. The asset class of corporate bonds is additionally considered in the empirical analysis, because it is also a main asset class which has feedback effects with the business cycle due to the correlation between the default risk and the real economy (Krainer (2004)). First, the linkages between the real economy and the market of long term government bonds, the money market, the market of corporate bonds and the stock market are described in sections 4.2.1 to 4.2.4. Then, the rela-

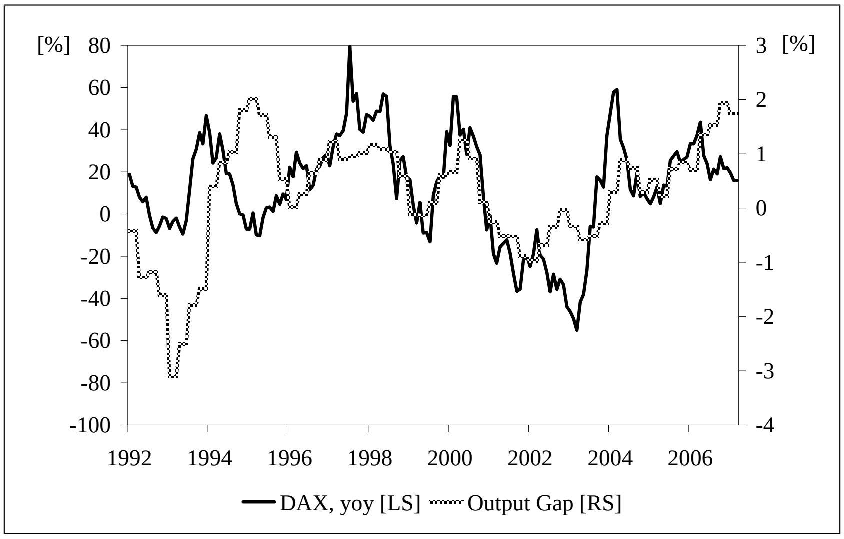

Figure 4.5: German output gap and year-on-year return of DAX.

tionship of the bond and the stock market is discussed in section 4.2.5. The various bidirectional linkages are empirically analysed by a VAR in section 4.5.[16]

4.2.1 Government Bonds and the Economy

This section deals with the effects of the real economy on the yield curve of government bonds and vice versa. As the influence of the macroeconomy on the term structure of interest rates has already been analysed in chapter 2, this section deals with the effects from the term structure on the real economy. There is a remarkable amount of literature on the usefulness of the term structure as an indicator for future economic events.[17] A highly regarded article is Estrella and Hardouvelis (1991). They use quarterly data for real GNP, the three-month T-bill rate and the ten-year government bond rate between 1955 and 1988 for the United States. The slope, i.e. the spread between the short and the long term interest rate, has predictive power for real GNP up to 16 quarters for cumulative changes and up to six quarters for marginal changes. Furthermore, the slope of the term structure is able to predict the components of GNP.

In contrast to the slope of the term structure which is a predictor for real economic

[16]The hypothesis which are tested by the VAR analysis are summarised in table 4.2.

[17]See Rosenberg and Maurer (2008) for a recent discussion of the term structure as a predictor for real economic activity in the light of the conundrum of long term interest rates and the term premium.

activity, the level of short and long term interest rates have been considered as coincident or lagging indicators in the past, because they tend to peak with or after the business cycle (Cullity and Moore (1988)). Nevertheless, recent articles analyse whether the level of the short term interest rate has predictive power for real economic activity and whether it has even more predictive power than the term spread (section 4.2.2). This hypothesis is empirically tested in section 4.5.

As this empirical analysis deals with the feedback effects between the real economy and financial markets, actual and expected inflation is implicitly included in the nominal interest rate of government bonds. The reason is that the nominal long term interest rate of government bonds consists of four components (Wu (2006)): the real interest rate, the real interest rate risk premium, the expected inflation and the inflation risk premium. The effects of inflation on the long term interest rate have been discussed in the macroeconomic model of the yield curve in chapter 2. Hence, the predictive power of the bond market (the slope of the term structure) for inflation is discussed in the following lines.

If the term structure of interest rates of the bond market is a useful variable to forecast inflation, it is of interest for central banks.[18] If the central bank considers the predictive power of the term structure, historical and current yield curves influence future monetary policy. Otherwise, the term structure has no predictive power and is simply a shadow of future expected monetary policy (Estrella and Hardouvelis (1991)).

Seminal articles about the term structure of interest rates as a predictor for inflation are Fama (1990), Mishkin (1990a) and Mishkin (1990b). Fama states a relationship between inflation and the spread of the interest rates of five- and one-year bonds as well as a relationship between the change of the inflation rate one year ahead and the real return of a one-year bond. Mishkin (1990a) uses the current term spread of nominal long term yields with maturities up to five years and the one-year bond market rate to forecast inflation. He concludes that the term structure of bonds with longer maturities has predictive power for changes in future inflation, but only little predictive power for the term structure of real interest rates. In a similar analysis, Mishkin (1990b)

[18]Besides, central banks use the information of the term structure of interest rates as a predictor for economic growth.

researches on the forecasting ability of the term structure of short term Treasury bills with maturities between one and twelve months. He finds that nominal short term interest rates with maturities up to six months can predict the real term structure but not inflation. The term spread between Treasury bills of nine and twelve months can forecast future inflation but not real interest rates.

4.2.2 Money Market and the Economy

The relationship between the money market and the real economy is also bidirectional. The effect of the real economy on the money market rate by the Taylor rule for monetary policy is presented in section 2.4.3 above. The other direction of the relationship is analysed by Ang, Piazzesi and Wei (2006) who conclude that the nominal short term interest rate is a better predictor for GDP growth than the slope of the term structure in the United States between 1952 and 2001.[19] They use the Expectations Theory (section 1.3.3) and divide the observed term spread between long term maturities up to five years and the three-month interest rate into two components: one part is the spread demanded by a risk neutral investor according to the Pure Expectations Hypothesis (PEH-spread). The remaining part is due to a risk premium demanded by a risk averse investor. They split the analysis into two different regressions. First, they analyse the correlation of expected future GDP growth and expected future yields (Pure Expectations Hypothesis). Then, they focus on the correlation of expected future GDP growth and the demanded risk premium (Expectations Hypothesis).

For the first regression it is necessary to calculate the risk premium as the difference between the observed spread and the PEH-spread. Therefore the PEH-spread is computed with VAR dynamics. The GDP growth is explained in the following bivariate regression by the PEH-spread, the risk premium and the error term:

$$\text{GDP growth} = \beta_1 \cdot \text{PEH-spread} + \beta_2 \cdot \text{risk premium} + \text{error term}. \tag{4.1}$$

The second regression for GDP growth is univariate, whereas the explanatory variable

[19] Ang, Piazzesi and Wei (2006) give a list of articles that deal with the term structure of interest rates as a predictor for real activity.

is the observed term spread between the long and the short term interest rate:

$$\text{GDP growth} = \beta_1 \cdot \text{observed spread} + \text{error term.} \tag{4.2}$$

Ang, Piazzesi and Wei conclude that the ability to forecast GDP growth is higher in the bivariate than in the univariate regression. Nevertheless, as the risk premium in the bivariate regression is insignificant, a univariate regression with the PEH-spread alone is a better predictor for GDP growth than the observed term spread. They find that the PEH-spread is highly correlated with the short term interest rate, whereas the latter is mean reverting and consequently predictable. Therefore, the short term interest rate itself is a good predictor for GDP growth. This proposition by Ang, Piazzesi and Wei is empirically tested in section 4.5.

4.2.3 Corporate Bonds and the Economy

Another main asset class of financial markets in Germany is the market of corporate bonds, even though the outstanding volume and liquidity of corporate bonds is smaller than that of government bonds. A credit or corporate bond is a security issued by a company to raise capital on financial markets. Corporate bonds are usually priced relative to virtually risk-free assets like short term money market securities or long term government bonds.

Due to the default risk of the firm, corporate bonds are riskier than government bonds of industrial countries. Consequently, the market price of corporate bonds mainly depends on this default risk, which is measured by rating agencies such as Moody's, Standard & Poor's or Fitch Ratings. However, the corporate credit spread is significantly higher than what would be justified by the default risk alone. The reason is that investors demand a liquidity premium and a risk premium which compensates (among other things) for the volatility of the default risk. Besides, Elton et al. (2004) find in an empirical study that the corporate bonds in a rating category are heterogeneous so that the rating category is not a sufficient measure of the default risk of a corporate bond. The reason is that investors consider further variables like a finer categorisation of the rating classes, different liquidities of the bonds, different rating classifications by the rating agencies or rating differences between the company and its bond.

Krainer (2004) relates the corporate spread to the real economy, because the business cycle influences the default risk and the liquidity of corporate bonds. Accordingly, the corporate spread has a tendency to widen in a recession and to narrow in an expansion as the default risk is pro-cyclical. The difference between corporate spreads of bonds with different ratings is smaller when the economy is in a boom than in a contraction. The reason is that the liquidity of corporate bonds increases in expansions, because investors have a lower risk aversion and are willing to hold risky corporate bonds. Especially in the early phase of an economic recovery, the target rate of the central bank is still low which enhances the overall liquidity in the financial system. Analogous, the liquidity of corporate bonds decreases when the economy is in an upswing. The link between the interest rates of corporate bonds and the real economy is empirically analysed in section 4.5.

4.2.4 Stocks and the Economy

One of the first studies of the relationship between US stock indices and the business cycle is Mennis (1955). The ability of stock prices to indicate business activity was often rejected due to the experience from 1939 to 1942, where stock prices were declining amid an expansionary economy. Similar, in 1946 and the following years, stock prices were basically flat even though economic activity increased. According to Mennis, the interdependence between stocks and the economy can be analysed either by the levels or by the cyclical turning points. Empirical evidence for the later is that stock prices often changed direction before the real economic activity between 1871 and 1949.

There are several rationales for the stylised fact that the stock market reaches its turning points before the real economy (Cullity and Moore (1988)). The stock market is leading the economy, because profits and interest rates are the main drivers of stock prices. Profits are mainly driven by the two factors profit margins and new orders, whereas both factors have their cyclical turning points before the business cycle. Therefore, the stock market changes direction before the real economy. This pattern is enhanced by the level of interest rates, which is unusually high before an upper and unusually low before a lower turning point of the business cycle. The level of interest rates influences the stock price, because the present value of future earnings of the company depends on the discount rate. Furthermore, the level of interest rates influences the availability of profitable investment opportunities for firms what in turn determines the stock price.

DuBois (1992) also discusses the leading function of stocks over the economy. The attractiveness of stocks is significantly reduced during the latter phase of an upswing of the economy, because the excess liquidity that has supported the demand for stocks in the early stage of the cyclical economic recovery has vanished due to a restrictive monetary policy. Higher input costs and a lower productivity as well as a slowing growth of sales also reduce the attractiveness of stocks. As investment plans for the future are reduced due to the higher level of interest rates, future profitability of the firms decreases. Consequently, a downswing is likely which lowers corporate profits and stock prices. This negative outlook makes the asset class of stocks less attractive. The lead of the stock market over the real economy will be empirically tested in section 4.5.

There are also effects from the stock market on the real economy. Ludvigson and Steindel (1999) research on the effects of price changes in the stock markets on the real economy. This research is closely related to the general wealth effect on consumption, i.e. on real economic activity (Lettau and Ludvigson (2004)). However, the effects from the real economy on the stock market are more important to the Top-Down approach to Asset Allocation.

4.2.5 Stocks and Bonds

The results in the literature on the forecasting ability of the bond market for stock returns depend on the time period as well as on the country and characteristics of the stock and bond market. The seminal article in this context is Campbell (1987) who states the ability of short term interest rates to forecast stock returns in the short term. Zhou (1996) uses the whole maturity spectrum of interest rates to forecast stock returns in the medium and long term.

Another stream in the literature deals with the correlation between the stock and

Hypothesis	
I	There exist feedback effects between the short term money market rate and the real economy.
II	There exist feedback effects between the return of the stock market (in excess to the short term money market rate) and the real economy.
III	There exist feedback effects between the interest rate of the government bond market (in excess to the short term money market rate) and the real economy.
IV	There exist feedback effects between the interest rate of the corporate bond market (in excess to the short term money market rate) and the real economy.
V	The short term money market rate is a better predictor for real economic activity in the next twelve months than the slope of the term structure.
VI	Rising stock markets are bad news for bond markets in the short term.

Table 4.2: Overview of hypotheses which are empirically tested in section 4.5.3.

the bond market. In the long term, Campbell and Ammer (1993) find a slightly positive correlation between the long term movement of the return of stocks and bonds, because there are common variables (for example the term spread) that influence the excess returns of both stocks and bonds. Another rationale for the positive correlation of the excess returns of stocks and bonds is the negative relationship of both with the real interest rate. However, expected inflation reduces the correlation, because it has a negative effect on bonds (higher expectations of long term inflation yield a higher level of overall interest rates) and a positive effect on stocks (higher expectations of long term inflation are accompanied by higher expectations of real economic activity). Campbell and Ammer state that the negative correlation between expectations of inflation and future stock returns is contrary to some previous literature. This contradiction may be due to the exact specification of the inflation variable (e.g. contemporaneous inflation, level of expected inflation or change of expected inflation).

In the short term, the correlation of stocks and bonds can be time-varying or even temporarily negative (Connolly, Stivers and Sun (2004)). The reason is that an increase in the uncertainty in financial markets, which is measured by the implied volatility of equity index options, yields a higher increase in bond returns than in stock returns.[20] The hypothesis, that a short term increase in the stock market causes a decline in the

[20] Similarly, Connolly, Stivers and Sun (2004) find that an unexpected high detrended turnover in stock markets makes bond returns more attractive relative to stock returns.

bond market, is empirically tested in section 4.5.

The correlation of stocks and bonds is also considered in Tactical Asset Allocation. For example, Hartpence and Sikorav (1996) construct a strategy based on long term values of stocks and bonds given by valuation models. They assume that movements of stocks and bonds are correlated in the long term and that current deviations of the prices from their fair values are corrected in the short term. Hence, they use an error correction framework to quantify the expected movements of the asset prices. When they apply their model to the French and international markets to forecast future returns, they achieve a higher return (with a lower or equal risk) than the return of the benchmark portfolio given by Strategic Asset Allocation.

4.3 Data Description

4.3.1 Financial Market Data

This chapter analyses the relative attractiveness of the main German asset classes during the German business cycle with a data set consisting of the interest rates of ten-year government bonds, of corporate bonds, the three-month money market rate, the year-on-year return of stocks and the output gap. In the empirical analysis, the interest rates or returns are measured in excess to the riskfree rate. This approach is called the Building Block approach (Siegel and Ibbotson (1988)) because of the riskfree component and the risk premium. The risk premium demanded by investors compensates for bearing risk (amongst others) of the expected inflation rate, the expected real riskfree interest rate and the default risk. The short term riskfree interest rate is approximated by the three-month money market rate, so that the returns and interest rates in financial markets are comparable (Arnott and Henriksson (1988)). As Finance is based on expected return and risk, the latter is included in the analysis by relating the interest rates and returns to the riskfree short term interest rate.

The data for the equity market is the German DAX index, which fulfils the conditions stated by Mennis (1955) to be an appropriate stock index for an empirical analysis. Accordingly, the index should include a large part of the market value of listed shares, has

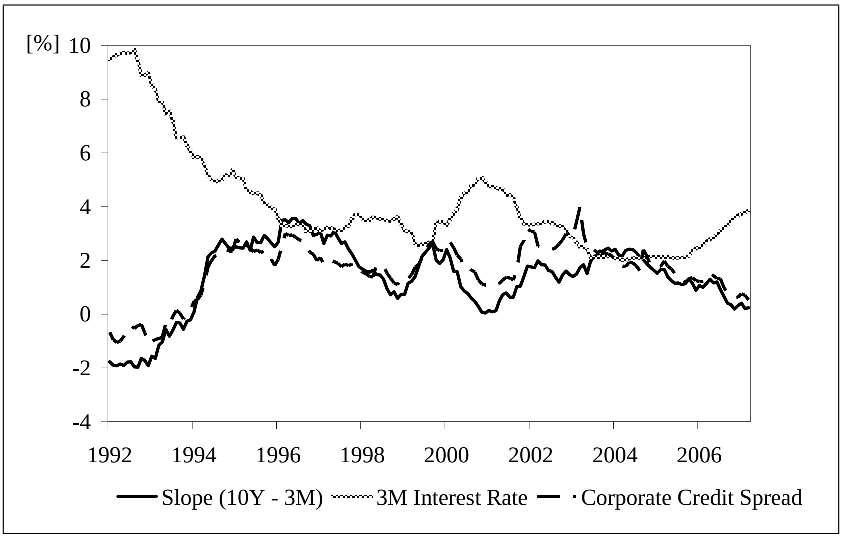

Figure 4.6: German three-month money market rate, interest rate of ten-year government bonds minus three-month money market rate (slope) and interest rate of corporate bonds minus three-month money market rate (corporate credit spread).

to be adjusted for stock splits, has to be diversified over all industries and its time series should be of reasonable length. Furthermore, the DAX index is a performance index, that is dividends paid to the shareholders are theoretically reinvested and therefore included in the time series of the DAX index. The stock market is represented by the total year-on-year return on a monthly frequency in line with the suggestions by DuBois (1992). As the year-on-year return of the DAX index is very volatile, a twelve-month moving average is used. In contrast to interest rates of fixed income securities, the nominal future returns of equities are uncertain. That is why today's return of the DAX index is taken as the best guess for tomorrow's return (naive forecast).[21]

The data for the DAX, interest rates of government bonds, money market rates and corporate bonds is collected from the Deutsche Bundesbank. The Deutsche Bundesbank calculates the interest rate of government bonds with a maturity of ten years based on listed Federal securities with the Svensson method, which is an extended Nelson-Siegel approach. The short term riskfree interest rate is the three-month money market rate between banks in Frankfurt. The data for the interest rate of corporate bonds is the yield of outstanding corporate bonds of domestic firms. The three time series of interest rates are depicted in figure 4.6.

[21] Figure 4.7 shows the transformed return series of the DAX index.

4.3.2 Real-Time Output Gap Estimate

As a measure of the economy, the output gap is used, which has strong feedback effects with financial markets. This fact is captured by Diermeier, Ibbotson and Siegel (1984) in their concept of macroconsistency, where they attribute the supply of aggregated financial market returns to real business activity and productivity of firms. However, the distribution of aggregated returns among investors depends on the demand for the various asset classes. That is why the concept of macroconsistency is often omitted in the daily analysis of financial markets.

The output gap measures the ability of the real economy to generate financial market returns. The output gap is a well-known concept in Macroeconomics and Financial Economics. It is defined as the deviation of the growth rate of the real economy from its potential growth rate. The potential growth rate of the economy is its long term growth rate without economic slack or exogenous shocks. It is determined by structural factors of the economy like the growth of productivity and of employment.[22]

Even though the concept of the output gap is criticized due to measurement problems, it is often used in the macroeconomic literature. One of the first who researched on the real-time estimation of the output gap were Orphanides and van Norden (2002). They state that the real-time measurement of the output gap is important, because the output gap might be revised after its initial release. The magnitude of the revision can have the same size as the output gap itself and is the largest around the turning points of the economy. This is a problem for policy makers, because correct information about the output gap is very important for their decisions during turning points.

The output gap which is used in this analysis is based on a real-time GDP series for Germany from the Deutsche Bundesbank. This real time series consists of initial releases of real GDP, that is revisions are not included. The estimation method is the real-time estimate of Orphanides and van Norden, which is a two step procedure. First, a subperiod of the sample is chosen that starts at the beginning and ends at an arbitrarily chosen date in the middle of the sample. For this subperiod, a real-time estimate of real GDP growth is obtained by detrending the GDP growth time series over this subperiod.

[22]Another measure of the state of the economy is the Non-Accelerating Inflation Rate of Unemployment (NAIRU).

This procedure is repeated until the end of the sample is reached, whereas the subperiod is enlarged successively by one period. Second, the last periods of the various subperiods are combined to a new time series of real-time output gap estimates. For the analysis of the amount of total revision of the estimated output gap, Orphanides and van Norden compare the real-time estimate of the output gap with the final estimate. The final estimate is the detrended historical time series of real GDP growth up to the most current release, whereas it contains historical revisions in real GDP growth.

In order to forecast the trend of the growth of the output, it is necessary to divide the time series of GDP growth into a trend and a cyclical component. It is common to apply the Hodrick-Prescott (1997) Filter (HP-Filter) for this division. For example, Bouthevillain et al. (2001) use the HP-Filter in their research on cyclically adjusted budget balances. The HP-Filter is simple, transparent and yields useful results. Nevertheless, the HP-Filter is not able to detect a trend shift shortly after the structural break has occurred.[23] A further drawback of the HP-Filter is the end of sample problem.[24] It is due to the fact that the estimated trend component is a weighted average, so that the trend component is mainly influenced by recent values. To reduce this bias, it is common to run the HP-Filter over an enlarged sample which consists of the historical time series and an out-of-sample forecast. Therefore, in this analysis, the historical sample of the yearly rate of change of real GDP growth is enlarged by forecasts. The forecasts are generated by an AR(4) process, which is appropriate according to Döpke (2004). The ratio of the number of available observations of real GDP growth to the number of periods forecasted by the AR(4) process is held constant at a ratio of 4:1, because the number of available observations is time-varying.[25]

The output gap in this chapter is calculated as the actual value of GDP growth minus the trend component of GDP growth (potential growth). A positive (negative) output gap indicates that the economy grows above (below) its potential growth rate.

[23] A two-sided moving-average is also not able to detect a structural break quickly.

[24] Orphanides and van Norden (2002) depict the end of sample problem as the main problem, because real-time estimates for the potential growth rate of GDP are very unreliable at the end of the sample.

[25] The time-varying number of available observations of the sample is due to the different base dates in the data set of real time GDP provided by the Deutsche Bundesbank.

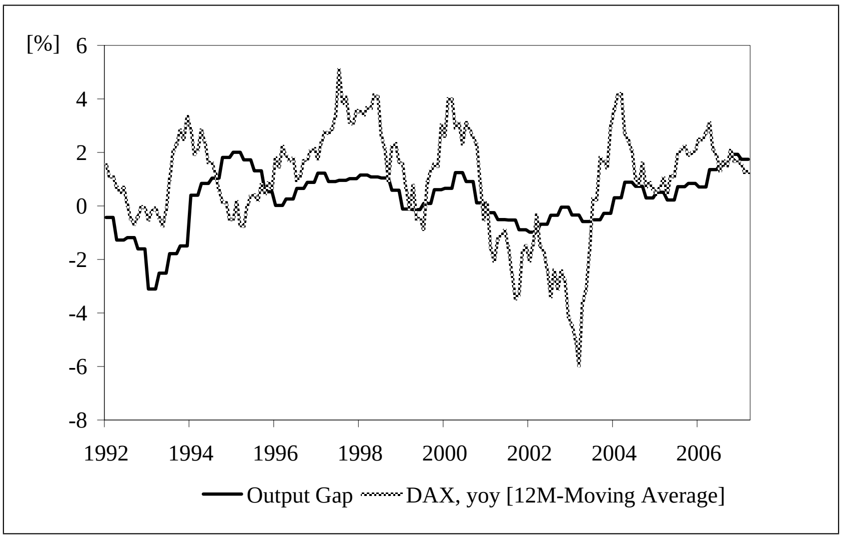

Figure 4.7: German output gap and twelve-month moving average of year-on-year DAX returns.

Furthermore, an increase (decrease) in the actual GDP growth or a decrease (increase) in the potential growth rate increases (decreases) the output gap. Figure 4.7 shows the real-time estimate of the output gap and the year-on-year return of the DAX index. Both of them are stationary (I(0)) and can be used in the following VAR analysis. Due to the fact that GDP is available at a quarterly frequency and the financial market variables have a monthly frequency, the estimate of the real-time output gap is used for three successive months.

4.4 Empirical Analysis of Asset Classes and the Economy

There is a close relationship between the main asset classes and the real economy. This is formulated by Arnott and Henriksson (1988): "Capital markets do not exist in a vacuum. Asset values do not rise and fall of their own accord. Rather, they embody the views of the investment community about future macroeconomic prospects." In general, stock returns mainly depend on GDP and bond returns mainly depend on GDP and inflation. As a consequence, an active approach to Asset Allocation based on forecasts of GDP and inflation (Top-Down approach) yields a higher return, because the time-varying relative attractiveness of stocks and bonds is considered in the short term asset mix. Even with less than perfect forecasts of the highly uncertain macroeconomy, the Top-Down approach yields higher returns than a passive approach (Siegel and Ibbotson (1988)). The Top-Down approach focuses on the effects from the economy on financial markets. However, there are also effects from financial markets on the economy, e.g. price changes of assets have a wealth effect on consumption (Ludvigson and Steindel (1999) as well as Lettau and Ludvigson (2004)).

There are several reasons why financial markets influence the real economy, i.e. financial markets are leading indicators. For example, stock market investors might forecast turning points in the business cycle, they might react to developments which cause the turn of the business cycle or movements in stock prices might lead to the turn of the business cycle (Cullity and Moore (1988)).

Consequently, a non-structural and unrestricted VAR analysis is appropriate to quantify the sign and size of the various feedback effects between financial markets and the real economy. An advantage of an unrestricted VAR analysis is that an a priori classification of the variables as endogenous or exogenous and a theoretical ex ante specification of the equations is not necessary (Sims (1980)). As economic theory does not provide a detailed theory for every single relationship between the various asset classes and the real economy, an unrestricted VAR analysis is used in this empirical research. The estimation of a VAR is important, because Tactical Asset Allocation assumes that the Efficient Market Hypothesis does not hold at any time, so that historical asset returns as well as historical economic variables should have a significant explanatory power for today's asset prices. A VAR analysis also takes into account that today's prices in financial markets depend on expectations. Therefore, the relationship between the economy and variables of financial markets is intertemporal. The small number of time series included in the VAR analysis allows a parsimonious specification. In this VAR analysis, only small number of lags is necessary, so that the number of parameters that have to be estimated is small as well as the loss in degrees of freedom. Even though the number of included lags is small, the inclusion of the history of all variables in the information set to forecast a single variable improves the forecast accuracy (Verbeek (2004)).

Each equation of the VAR is separately estimated by OLS, as this procedure gives

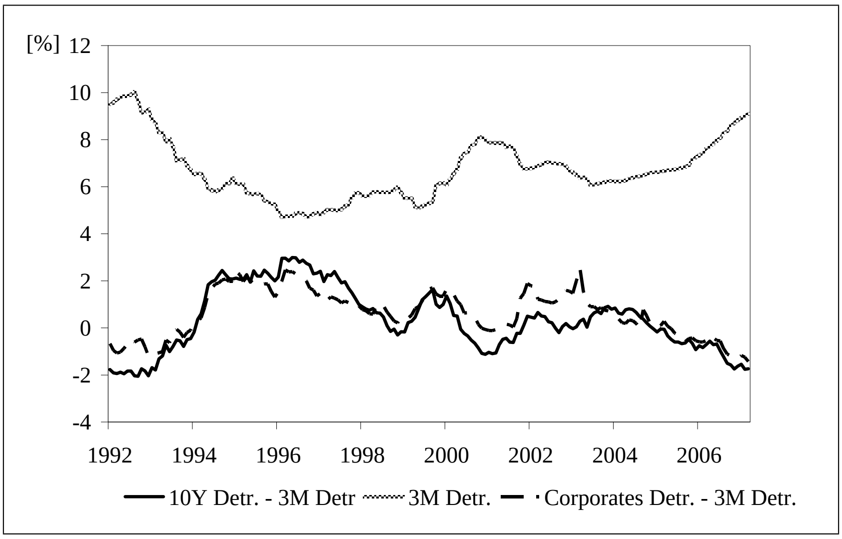

Figure 4.8: Detrended three-month money market rate, detrended interest rate of ten-year government bonds minus detrended three-month money market rate and detrended interest rate of corporate bonds minus detrended three-month money market rate.

better results than simultaneous-equation models (Gujarati (1995)). To obtain consistent and efficient estimates of the VAR with OLS, the right hand side variables have to be the same in every equation of the VAR and the time series have to be stationary. To fulfil the condition of stationarity, the interest rate time series of the data set are linearly detrended. The time series of the long term bond interest rate minus the short term interest rate, the interest rate of corporate bonds minus the short term interest rate and the short term interest rate itself are linearly detrended beginning from January 1992 until March 2007 (figure 4.8). The detrended time series of interest rates as well as the return of the equity market and the output gap are mean reverting and stationary.[26]

In a VAR analysis, it is critical to determine the lag length of the variables. Pindyck and Rubinfeld (1998) state that the data should determine the dynamic specification of the VAR, whereas Verbeek (2004) suggests choosing the lag length in dependence on the Akaike or Schwarz information criteria or in dependence on the statistical significance. Applying these criteria in this analysis yields a VAR with a leg length of two (VAR(2)) for the output gap and the financial market time series.[27] A VAR(2) specification has

[26]Preliminary research has shown that a VAR consisting of the first differences of the time series described above does not yield meaningful results. The impulse response functions show erratic swings which end between three and nine months after the shock has occurred.

[27]Additional test statistics for the lag length reported by EViews also suggest the specifica-

the advantage that it is transparent and parsimonious (Diebold, Rudebusch and Aruoba (2005)).

4.5 Estimation Results

The various bidirectional feedback effects between the business cycle and the main asset classes are empirically analysed by Granger Causality tests (section 4.5.1), an estimation of a VAR (section 4.5.2) and impulse response functions of the VAR analysis (section 4.5.3). The empirical results are summarised in section 4.5.4.

4.5.1 Granger Causality Tests

In contrast to a VAR analysis, the Granger Causality Test only considers the interdependencies of two time series. Table 4.3 consists of the pairwise results of the Granger Causality Tests for the time series included in this analysis. As the results of the Granger Causality Tests depend on the number of lags of the variables, the test results are reported for the lag lengths of two, four, eight and twelve.

The Granger Causality Tests suggest that the output gap and financial markets have various significant relationships. At the ten percent level of significance, 33 of 80 linkages are significant when two, four, eight or twelve lags are included. For example, the last row of table 4.3 shows that the Null Hypothesis of no Granger Causality of the stock market to the output gap is rejected at least at the ten percent significance level for the lag lengths of two, four, eight and twelve. Hence, the time series of the output gap significantly depends on historical values of the stock market. This result confirms the stock market as a leading indicator for real economic activity.

4.5.2 Vector Autoregression Analysis

The Vector Autoregression of this analysis systematically quantifies the relationships between the main asset classes and the real economy in a set of equations. As an example, equation 4.3 shows the estimated equation for the bond market explained by

tion of a VAR(2).

Included Number of Lags	2	4	8	12
	p-val.	p-val.	p-val.	p-val.
Bonds do not Granger-Cause Credit	0.000	0.001	0.033	0.051
Bonds do not Granger-Cause Money	0.186	0.167	0.073	0.009
Bonds do not Granger-Cause Output Gap	0.222	0.173	0.083	0.048
Bonds do not Granger-Cause Stocks	0.499	0.804	0.540	0.268
Credit does not Granger-Cause Bonds	0.182	0.214	0.194	0.075
Credit does not Granger-Cause Money	0.526	0.208	0.175	0.208
Credit does not Granger-Cause Output Gap	0.869	0.264	0.549	0.429
Credit does not Granger-Cause Stocks	0.888	0.766	0.723	0.811
Money does not Granger-Cause Bonds	0.001	0.004	0.004	0.015
Money does not Granger-Cause Credit	0.078	0.070	0.166	0.218
Money does not Granger-Cause Output Gap	0.077	0.074	0.004	0.002
Money does not Granger-Cause Stocks	0.388	0.537	0.658	0.684
Output Gap does not Granger-Cause Bonds	0.007	0.158	0.311	0.214
Output Gap does not Granger-Cause Credit	0.204	0.053	0.025	0.045
Output Gap does not Granger-Cause Money	0.005	0.038	0.010	0.035
Output Gap does not Granger-Cause Stocks	0.468	0.651	0.057	0.158
Stocks do not Granger-Cause Bonds	0.632	0.285	0.250	0.461
Stocks do not Granger-Cause Credit	0.448	0.705	0.435	0.673
Stocks do not Granger-Cause Money	0.056	0.324	0.414	0.541
Stocks do not Granger-Cause Output Gap	0.004	0.094	0.014	0.022

Table 4.3: Granger Causality Tests of financial market time series and output gap (each test is based on 171 observations).

two lags of the other main asset classes and the output gap:

$$\begin{aligned}\text{Bonds}_t &= \beta_0 + \beta_1\text{Bonds}_{t-1} + \beta_2\text{Bonds}_{t-2} + \beta_3\text{Money}_{t-1} + \beta_4\text{Money}_{t-2} \\ &\quad + \beta_5\text{Credit Spread}_{t-1} + \beta_6\text{Credit Spread}_{t-2} + \beta_7\text{DAX}_{t-1} \\ &\quad + \beta_8\text{DAX}_{t-2} + \beta_9\text{Output Gap}_{t-1} + \beta_{10}\text{Output Gap}_{t-2} + \varepsilon_t. \end{aligned} \tag{4.3}$$

In a VAR, it is appropriate to measure the significance of the various relationships by the joint significance of the variables in one of the estimated equations (Gujarati (1995)). Therefore, the statistical significance of a single lagged explanatory variable and its coefficient have no meaningful interpretation. It is common for a VAR analysis that only a quarter of the single lagged variables are significant (Pindyck and Rubinfeld (1998)). This characteristic of the results of a typical VAR estimation is represented by the results of the VAR analysis of this chapter (table 4.4). The high statistical values of the F-test for each equation indicate that the joint significance of the lagged variables is strong.

4.5.3 Impulse Response Functions

Impulse response functions are used to quantify the effects of the lagged variables included in the VAR, because the joint significance has no meaning in terms of the size and sign of the effect of a single variable in the equation. The impulse response function quantifies the impulse of a one-period exogenous shock (typically of one standard deviation) to one variable on the other variables in the estimation equation of the VAR (Pindyck and Rubinfeld (1998)). It is assumed that the contemporaneous and historical values of the other variables in the VAR are unchanged (Hamilton (1994)).

181 observations	Bonds	Money	Credit	Stocks	Output Gap
Constant	0.329	0.087	0.119	0.804	0.280
	(1.626)	(0.668)	(0.597)	(0.943)	(1.054)
Bonds_{t-1}	0.910	0.105	0.319	-0.194	0.012
	(9.874)	(1.780)	(3.519)	(-0.500)	(0.097)
Bonds_{t-2}	0.058	-0.146	-0.256	0.549	0.052
	(0.615)	(-2.435)	(-2.772)	(1.388)	(0.422)
Money_{t-1}	-0.363	1.376	0.112	-0.325	0.207
	(-2.680)	(15.887)	(0.845)	(-0.571)	(1.163)
Money_{t-2}	0.317	-0.390	-0.123	0.257	-0.239
	(2.318)	(-4.459)	(-0.916)	(0.447)	(-1.330)
Credit_{t-1}	0.088	0.039	1.065	-0.084	0.014
	(1.033)	(0.713)	(12.715)	(-0.235)	(0.128)
Credit_{t-2}	-0.103	-0.010	-0.170	-0.365	-0.088
	(-1.203)	(-0.174)	(-2.010)	(-1.009)	(-0.780)
Stocks_{t-1}	-0.010	0.020	-0.014	1.822	0.021
	(-1.072)	(3.544)	(-1.541)	(48.032)	(1.793)
Stocks_{t-2}	0.010	-0.021	0.014	-0.841	-0.022
	(1.128)	(-3.659)	(1.582)	(-22.518)	(-1.885)
Output Gap_{t-1}	0.080	-0.021	0.016	0.029	0.886
	(1.347)	(-0.539)	(0.277)	(0.114)	(11.319)
Output Gap_{t-2}	-0.119	0.069	-0.049	-0.145	0.037
	(-2.052)	(1.873)	(-0.864)	(-0.595)	(0.483)
R-Squared	0.975	0.989	0.957	0.997	0.934
Adjusted R-Squared	0.974	0.988	0.955	0.997	0.930
Sum of Squared Residuals	7.875	3.224	7.620	139.742	13.549
Standard Error	0.215	0.138	0.212	0.907	0.282
F-Statistic	674.5	1515.8	380.5	5645.6	239.8
Akaike Information Criteria	-0.175	-1.068	-0.208	2.701	0.367
Schwarz Criteria	0.019	-0.874	-0.014	2.895	0.562
Akaike Information Criteria	1.232				
Schwarz Criteria	2.204				

Table 4.4: Results of VAR estimation (t-values in parenthesis).

In this analysis, the output gap is defined as the actual real-time value of GDP growth minus the trend component of GDP growth. Hence, a positive output gap signals an expansionary phase in the business cycle. The discussion of the linkages between the business cycle and financial markets in section 4.2 yields a set of hypotheses that will be tested with the impulse response functions of the VAR analysis. As the hypotheses deal with the general existence of permanent feedback effects, it is difficult to distinguish between lead and lag relationships. However, the sign, size and length of the time period of the effect of one variable on another are subject of the hypotheses.

The feedback effects between the various financial markets and the real economy as well as between the main asset classes are shown in figure 4.9. The estimated sign, size and significance of these effects are determined by the corresponding impulse response functions of the VAR analysis. The magnitudes of the impulse response functions are similar to the magnitudes obtained by Ang and Piazzesi (2003) who estimate an unrestricted VAR for the dynamics of the term structure of interest rates. However, some impulse response functions in figure 4.9 have confidence bands that partially include the zero line. If the confidence band is not entirely below or above the zero line during a time interval after the shock, it cannot be confirmed that the effect is statistically different from zero during this time interval. Nevertheless, the characteristic of the impulse response function of this VAR analysis can also be found in related articles in Financial Economics like Diebold, Rudebusch and Aruoba (2005) and Hördahl and Tristani (2007). Both use a VAR analysis with a similar number of explanatory variables and state the existence of effects between the variables included in the VAR, even though the confidence band partially includes the zero line. Therefore, it is appropriate to state the existence of effects in this VAR analysis, too. Accordingly, the set of hypotheses (table 4.2) is empirically tested in the following lines.

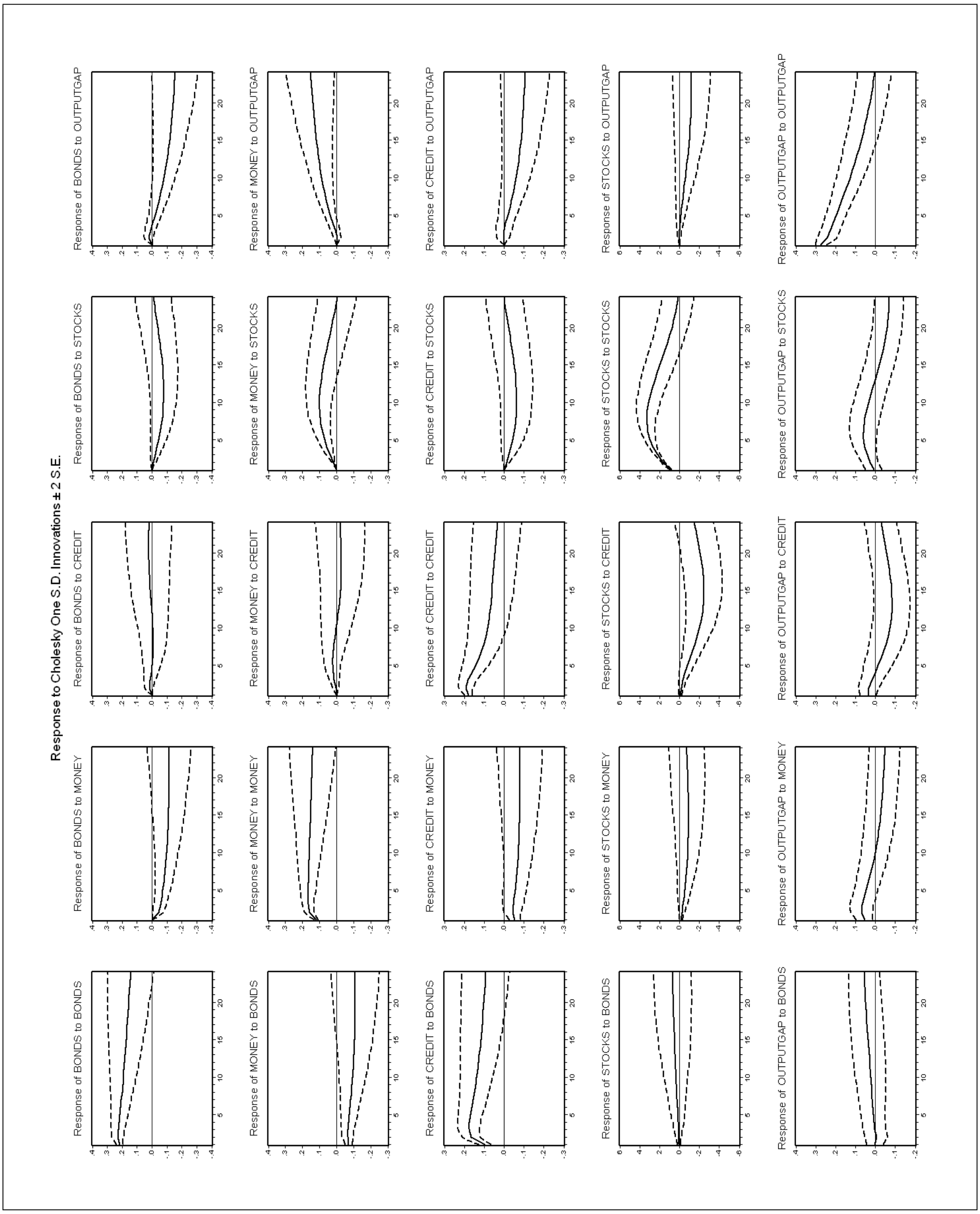

Figure 4.9: Impulse response functions for 24 months after the initial shock.

Hypothesis I: There exist feedback effects between the short term money market rate and the real economy.

The impulse response function of the reaction of the output gap to an increase in the money market rate is given in figure 4.9 in row five and column two.[28] This chart 5/2 shows that after an initial increase of one standard deviation of the short term interest rate, monetary tightening has a positive effect on the real economy in the first ten months. From eleven to 24 months, the reaction of the output gap to the increased money market rate is negative, which indicates a time lag of ten months until a tightening of monetary policy negatively affects the real economy.

The impulse response function of the reaction of the money market rate to an increase in the output gap of one standard deviation is represented in figure 4.9 in chart 2/5. After the initial increase in the output gap, the central bank increases the money market rate continuously over the next 24 months, whereas it raises its target rate in order to guarantee price stability in an expansionary economic environment. This is in line with a Taylor rule type of monetary policy (section 2.4.3). As there are bidirectional effects between the output gap and the money market rate, Hypothesis I cannot be rejected.

These two results have implications for the following interpretation of the VAR analysis, because the returns or interest rates of the other main asset classes in this chapter are adjusted by the riskfree short term money market rate to analyse the relative attractiveness of the main asset classes. Consequently, to infer on the absolute attractiveness of one of the main asset classes during the business cycle, it is necessary to take into account the feedback effects between the short term interest rate and the real economy.

Hypothesis II: There exist feedback effects between the return of the stock market (in excess to the short term money market rate) and the real economy.

In figure 4.9 in chart 5/4, the impulse response function shows the effect of a positive shock of one standard deviation to the stock market on the output gap. The stock market is a leading indicator to the real economy, because the preceding increase in the stock market is followed by the output gap in the following twelve months, whereas

[28]The location of the chart which is discussed is given by r/c, whereas r represents the row and c the column of figure 4.9.

the effect reaches its maximum six months after the initial shock. The leading function of the stock market is theoretically motivated by DuBois (1992) (section 4.2.4). This leading function ends twelve months after the shock, as the effect turns increasingly negative.

The effect of a positive shock of one standard deviation to the real economy on the stock market is negative. According to chart 4/5 in figure 4.9, a higher activity in the real economy results in a continuously declining stock market return over the next 24 months. This negative reaction of the stock market is due to the fact that the stock market return is measured as excess return over the short term money market rate in this analysis (Hypothesis I). Consequently, the short term money market rate increases more than the return of the stock market. This is because the central bank tries to reduce the upward pressure on the price level by a higher short term target interest rate so that a cash investment yields a higher return. As the higher level of interest rates reduces the opportunity of firms to raise capital for investment projects by their bank or on financial markets, the valuation of stocks and consequently their prices decline.

Furthermore, the negative reaction of the stock market return to increased economic activity is a consequence of the leading indicator characteristic of the stock market, because the stock market is already declining when the real economic activity begins to increase. This is in line with Cullity and Moore (1988) who find that stocks experience the highest gains before the economy reaches the lower turning point in the business cycle. In this VAR analysis, the positive shock of one standard deviation to the output gap can be interpreted as an increase in real economic activity after the trough in the business cycle. That is, the substantial gains of the stock market have already occurred. Given the bidirectional feedback effects between the stock market and the economy, Hypothesis II cannot be rejected.

Hypothesis III: There exist feedback effects between the interest rate of the government bond market (in excess to the short term money market rate) and the real economy.

The impulse response function of the reaction of the output gap to a positive shock of one standard deviation to the bond market variable shows a modestly increasing reaction during the 24 months after the initial shock (figure 4.9 chart 5/1). As the interest rate of a long term bond is adjusted by the short term interest rate, the bond market variable is equal to the slope of the term structure of interest rates in this analysis. This positive reaction is in line with the research on the forecasting ability of the term structure for future economic activity (section 4.2.1), whereas a positive term spread indicates a higher future real economic activity and a negative term spread indicates a recession.

The effect of a positive increase in the output gap on the relative attractiveness of the bond market is strongly negative (figure 4.9 chart 1/5) and gains momentum until 24 months after the shock. As the bond market return is measured in excess to the short term money market rate, the strong negative reaction is due to an increase in the short term interest rate (Hypothesis I). As the magnitude of the increase in the money market rate is similar to the increase in the excess return of the long term interest rate, the positive output shock has almost no impact on the level of the interest rate of a ten-year government bond. Hypothesis III cannot be rejected, because the interest rate of a long term government bond in excess to the short term money market rate has feedback effects with the real economy.

Hypothesis IV: There exist feedback effects between the interest rate of the corporate bond market (in excess to the short term money market rate) and the real economy.

Chart 5/3 in figure 4.9 shows that a positive shock to the interest rate of corporate bonds in excess to the money market rate leads to a positive reaction of the output gap during the first four months after the initial shock. From five to 24 months, the reaction is negative, whereas the negative effect has the largest magnitude at about twelve months after the initial shock. The positive shock to the corporate bond market variable represents an increase in the risk premium of corporate bonds. Investors demand a higher risk premium for corporate bonds as a compensation for a higher expected risk for the economy and the firms (Krainer (2004)). A large part of the perceived risk by investors is due to the negative expectations of the future path of the economy. Therefore, the higher demanded risk premium based on negative expectations of the economy enhances the cyclical downswing of the economy, as higher interest rates for corporate bonds make investments of firms more expensive.

The effect of the real economy on the risk premium of corporate bonds is slightly negative (figure 4.9 chart 3/5). In comparison, the response of the short term interest rate to the positive shock of the output gap is positive (Hypothesis I). Hence, the net effect of an increase in the output gap on the level of interest rates of corporate bonds is slightly positive. The reason is that during an economic upswing, firms are in a better financial condition which results in a lower risk premium and lower corporate bond yields. However, this effect is overcompensated by the higher demand for capital of firms during an economic upswing. They generate a higher supply of corporate bonds, so that the prices decrease and the yields of corporate bonds increase. The risk premium of corporate bonds becomes smaller when the economy experiences an expansionary phase and vice versa. That is why Hypothesis IV cannot be rejected.

Hypothesis V: The short term money market rate is a better predictor for real economic activity in the next twelve months than the slope of the term structure.

Based on Hypotheses I and III and given the literature in Financial Economics on the forecasting ability of the slope of the yield curve and of the short term interest rate for the real economy, Hypothesis V tests for the better leading indicator. Figure 4.9 (chart 5/1) shows the effect of an increase in the bond market variable (slope of the term structure) and of an increase in the short term money market rate (chart 5/2) on the output gap. The effect of an increase in the slope of the term structure (of one standard deviation) on the output gap is slightly positive and increases slowly. In contrast to that, the effect of a positive increase in the short term money market rate (of one standard deviation) on the output gap increases quickly after the initial shock and declines to zero after ten months. Therefore, the short term effect within the first twelve months after the initial shock of the short term interest rate causes a higher reaction of the output gap than the slope of the term structure. Therefore, a change in the short term interest rate has a better forecasting ability for the future path of the real economy than the slope of the term structure.

Furthermore, the effect of an increase in the slope of the term structure on the output gap is continuous, whereas the effect of a higher short term money market rate on the output gap is cyclical. Considering the cumulative effect on the output gap during the first twelve months after the initial shock, an increase in the slope of the term structure has a smaller effect than an increase in the short term money market rate. Hence, the short term interest rate is a better predictor for the cyclical movement of the real economy over the next twelve months than the slope of the term structure and Hypothesis V cannot be rejected.

Hypothesis VI: Rising stock markets are bad news for bond markets in the short term.

In Hypothesis I to V, the bidirectional effects between the output gap and financial market variables are analysed. In contrast to that, Hypothesis VI only considers the linkage between two financial markets. Given the fact that the stock and bond market are the two most important financial markets, Hypothesis VI considers the effect of the stock market on the bond market, whereas both variables are adjusted by the short term interest rate.[29] The impulse response function (figure 4.9 chart 1/4) depicts a positive reaction of the government bond market (as long term interest rates are decreasing) to an increase of one standard deviation in the stock market. The effect has the largest magnitude at about twelve months, whereas the magnitude of the effect declines to zero 24 months after the initial shock. As an increase in the return of the stock market causes the prices of long term government bonds to increase, rising stock markets are good news for bond markets and Hypothesis VI has to be rejected.

4.5.4 Summary of Results

The feedback effects between the business cycle and the main asset classes are tested by Granger Causality tests and by a VAR analysis and its impulse response functions. The results of the Granger Causality tests confirm the bidirectional feedback effects between two time series, because nearly half of the conducted Granger Causality tests show a significant Granger Causality at the ten percent level of significance.

[29] As the focus of this analysis is the bidirectional linkages between the real economy and the main asset classes, the other feedback effects between financial markets in figure 4.9 are not discussed.

The results of the VAR analysis, i.e. the impulse response functions, also find bidirectional linkages, whereas the impact of the real economy on financial markets has a larger magnitude than vice versa. A positive shock to the output gap has a positive effect on the short term interest rate. The term spread between the interest rate of a long term government bond and the short term interest rate (term premium) decreases due to a positive shock to the output gap. Analogous, the risk premium of the interest rate of corporate bonds relative to the short term interest rate decreases. The difference between the year-on-year change of the stock market and the short term interest rate decreases due to a positive shock to the output gap. Consequently, the increase in the year-on-year change of the stock market has a lower magnitude than the increase in the short term interest rate as a reaction to the positive shock of the output gap.

4.6 Conclusion

The VAR analysis quantifies bidirectional effects between the real economy and financial markets and the correlation between the main asset classes. The Top-Down approach to Asset Allocation is based on the feedback effects between the real economy and the main asset classes, which are the focus of this chapter. However, the correlation between the main asset classes plays also a major role in Asset Allocation. The reason is that the correlation is important for the optimal diversification of the portfolio, as the gain from diversification is the larger, the lower the correlation between the single assets (Siegel and Ibbotson (1988)).

In general, the Lucas critique (Lucas (1976)) applies to the relationship between the macroeconomy and financial markets. Accordingly, the benefit of applying the Top-Down approach might be significantly reduced if all investor were aware of the relationships between the macroeconomy and financial markets and all investors pursued the Top-Down approach. Analogous, the term structure of interest rates might no longer be an indicator for future inflation, if the central bank made publicly that it considers the term structure of interest rates as information variable (Mishkin (1990b)).

There exist various meaningful possibilities for further research. A VAR analysis with additional asset classes, for example property, commodities, inflation indexed securities and foreign exchange could provide useful information for the Top-Down approach, as this analysis focuses on the main asset classes. Alternatively, the second moment of financial market and macroeconomic variables might be considered, because the sign and size of the bidirectional linkages between the macroeconomy and financial markets might depend on the (realized) volatility of the variables.

Further research could also analyse the expected return of the Top-Down approach depending on the phase of the business cycle. If all investors shift their assets from stocks to bonds in the midst of a downswing, the expected return from the Top-Down approach should be larger and have a lower volatility than in other phases of the business cycle. That is why Bahlmann, Hansul and Brendel (2007) suppose to consider the risk and return ratio of the various assets classes which may vary during the business cycle.

Chapter 5

Further Research in Financial Economics

The results of the three empirical analyses of this thesis show significant feedback effects between the real economy and financial markets. In the medium term, the yield curve of government bonds can be explained by the main macroeconomic variables output, inflation and monetary policy. The effect of these macroeconomic variables on the yield curve depends on the realized macroeconomic volatilities of output, inflation and monetary policy. In the short term, the announcement effect of the release of macroeconomic news on the yield curve is strongly significant for the most important business cycle indicators, which are mainly from the US. The feedback effects between the real economy and financial markets also determine the relative attractiveness of the main asset classes which is affected by the state of the economy in the business cycle.

An aspect of further empirical research on the feedback effects between financial markets and the real economy is to consider the conditional volatility of macroeconomic time series, even though macroeconomic models explain and forecast the conditional mean (Hamilton (2008)). Hamilton suggests the application of ARCH models in Empirical Macroeconomics, which would improve the quality of the parameter estimates in macroeconomic models. In the past, there has been far more research on the conditional variance in Empirical Finance than in Empirical Macroeconomics.

An ARCH framework could also be applied in Empirical Financial Economics, i.e.

on the feedback effects between the real economy and financial markets. As research in Financial Economics comprises financial and macroeconomic aspects, the macroeconomic part should also consider the conditional variance of the macroeconomic variables. Hence, the impact of past, current and expected macroeconomic volatility on the behaviour of economic agents in the economy and in financial markets will gain importance in future theoretical and empirical research in Financial Economics.

Another interesting aspect of further research on the linkages between the real economy and financial markets is to take into account inflation linked bonds. The asset class of inflation linked bonds has increased in market value in mature and emerging financial markets and experiences a steadily increasing attendance by investors. As the difference between the yield to maturity of nominal and inflation linked bonds (break even inflation rate) basically consists of inflation expectations and the inflation risk premium, these two parts could be part of research in Empirical Financial Economics. For example, Hördahl and Tristani (2007) use a Macro-Finance model of the term structure of interest rates to research on inflation risk premia as a part of the term structure of interest rates.

Appendix A

Macroeconomic Determinants of the Yield Curve

A.1 Pure Expectations Hypothesis

The Pure Expectations Hypothesis does not include a premium in the return of a long term investment. So, the excess return of a long term investment relative to a series of short term investments is zero. It can be shown that if the Pure Expectations Hypothesis holds for n periods, the one-period forward rate in $n-1$ periods is equal to the expected one-period spot rate in $n-1$ periods. The following presentation is based on Campbell, Lo and MacKinlay (1997).

The price of an n-period zero-coupon bond in period t which pays 1 monetary unit at maturity is P_{nt},

$$P_{nt} = \frac{1}{(1+Y_{nt})^n}, \tag{A.1}$$

whereas Y_{nt} is the yield to maturity of the n-period zero-coupon bond in period t,

$$1 + Y_{nt} = P_{nt}^{-(\frac{1}{n})}. \tag{A.2}$$

The one-period holding return of an n-period bond at time $t+1$ is $R_{n,t+1}$, whereas the n-period bond is bought in period t with a time to maturity of n periods and sold in the next period $(t+1)$ as an $(n-1)$-period bond,

$$1 + R_{n,t+1} = \frac{P_{n-1,t+1}}{P_{nt}}. \tag{A.3}$$

Using equation A.1, the one-period holding return $R_{n,t+1}$ can be formulated as a function of the yield to maturity of the bond at time t (Y_{nt}) and at time $t+1$ ($Y_{n-1,t+1}$),

$$1 + R_{n,t+1} = \frac{\frac{1}{(1+Y_{n-1,t+1})^{n-1}}}{\frac{1}{(1+Y_{nt})^n}} = \frac{(1+Y_{nt})^n}{(1+Y_{n-1,t+1})^{n-1}}. \tag{A.4}$$

The one-period forward rate F_{nt} at time t gives an investor a certain interest rate for a one-period investment in a zero-coupon bond[1] which begins in period n and ends in period $n+1$. The one-period forward rate F_{nt} is the result of buying a zero-coupon bond with a time to maturity of $n+1$ periods and re-financing this investment by selling

[1] Again, the zero coupon bond pays 1 monetary unit at maturity.

$P_{n+1,t}/P_{nt}$ n-period zero-coupon bonds, because selling $P_{n+1,t}/P_{nt}$ times an n-period bond with price P_{nt} at time t generates a positive cash flow to buy one $(n+1)$-period bond at time t $(P_{nt}(P_{n+1,t}/P_{nt}) = P_{n+1,t})$. At time $t+n$, the selling of $P_{n+1,t}/P_{nt}$ n-period bonds at time t generates a negative cash flow of $P_{n+1,t}/P_{nt} \cdot 1$. According to equation A.3, the return F_{nt} of this investment is determined by the price of the bond at time $n+1$ (which is 1) and by the price of the bond at time n (which is $P_{n+1,t}/P_{n,t}$),

$$1 + F_{n,t} = \left(\frac{1}{\frac{P_{n+1,t}}{P_{n,t}}} \right). \tag{A.5}$$

The forward rate $F_{n,t}$ can also be expressed in terms of the yield to maturity of an n-period and $(n+1)$-period bond (equation A.1),

$$1 + F_{n,t} = \frac{(1 + Y_{n+1,t})^{n+1}}{(1 + Y_{n,t})^n}. \tag{A.6}$$

The Pure Expectations Hypothesis, which states that the excess return of a long term investment relative to a short term investment is zero, can be applied to one period as well as to n periods. At time t, the Pure Expectations Hypothesis for one period equates the (known) return of a one-period bond Y_{1t} and the expected (unknown) one-period return of an n-period bond $E_t[1 + R_{n,t+1}]$,

$$1 + Y_{1t} = E_t[1 + R_{n,t+1}]. \tag{A.7}$$

The yield to maturity for one period at time t can be expressed in terms of the yield to maturity of bonds with a time to maturity of n and $n-1$ periods (using equation A.4 and the fact that Y_{nt} is known at time t),

$$1 + Y_{1t} = (1 + Y_{nt})^n \; E_t[(1 + Y_{n-1,t+1})^{-(n-1)}]. \tag{A.8}$$

At time t, the Pure Expectations Hypothesis for n periods equates the (known) return of an n-period bond and the expected (unknown) n-period return of a series of investments in one-period bonds,

$$(1+Y_{nt})^n = E_t[(1+Y_{1t})(1+Y_{1,t+1})...(1+Y_{1,t+n-1})]. \tag{A.9}$$

If the Pure Expectations Hypothesis for n periods (equation A.9) holds for all n, the definition of the forward rate (equation A.6) yields,

$$1+F_{n-1,t} = \frac{E_t[(1+Y_{1t})(1+Y_{1,t+1})...(1+Y_{1,t+n-1})]}{E_t[(1+Y_{1t})(1+Y_{1,t+1})...(1+Y_{1,t+n-2})]},$$

and respectively

$$1+F_{n-1,t} = E_t[1+Y_{1,t+n-1}].$$

At time t, the one-period forward rate in $n-1$ periods is equal to the expected yield to maturity of a one-period bond in $n-1$ periods.[2] Accordingly, at time t, the one-period forward rate for period $n-1$ is equal to the expected one-period spot rate in period $n-1$.

[2]If the Pure Expectations Hypothesis for n-periods (equation A.9) holds for all n, it follows that $1+Y_{1,t} = (1+Y_{n,t})^n \; E_t[(1+Y_{n-1,t+1})^{-(n-1)}]$. As interest rates are random and due to Jensen's Inequality ($E[1/X] \neq 1/E[X]$), the Pure Expectations Hypothesis cannot hold for one-period and for n-periods.

A.2 Correlations of Yields

Table A.1 contains correlations of interest rates for time to maturities between one month and ten years. The correlation in levels is presented in the lower triangular part of the matrix and is written in normal letters. The correlation in first differences is presented in the upper triangular part of the matrix and is written in cursive letters. Both parts of the table can be found in figure 2.5 for levels and in figure 2.6 for first differences in section 2.5.

Correlation between yields in levels (lower triangular part)	*Corrrelation between yields in first differences (upper triangular part)*												
	1M	3M	6M	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y
1M	1.000	*0.800*	*0.675*	*0.377*	*0.359*	*0.263*	*0.199*	*0.158*	*0.132*	*0.113*	*0.095*	*0.082*	*0.070*
3M	0.995	1.000	*0.877*	*0.510*	*0.469*	*0.384*	*0.327*	*0.287*	*0.257*	*0.232*	*0.206*	*0.185*	*0.163*
6M	0.989	0.992	1.000	*0.807*	*0.634*	*0.544*	*0.496*	*0.462*	*0.434*	*0.410*	*0.387*	*0.366*	*0.344*
1Y	0.960	0.963	0.988	1.000	*0.747*	*0.671*	*0.646*	*0.632*	*0.616*	*0.602*	*0.585*	*0.567*	*0.545*
2Y	0.931	0.937	0.967	0.988	1.000	*0.973*	*0.929*	*0.886*	*0.847*	*0.812*	*0.778*	*0.744*	*0.708*
3Y	0.900	0.910	0.942	0.971	0.995	1.000	*0.986*	*0.956*	*0.922*	*0.887*	*0.852*	*0.817*	*0.779*
4Y	0.874	0.885	0.919	0.953	0.984	0.997	1.000	*0.990*	*0.968*	*0.940*	*0.908*	*0.874*	*0.835*
5Y	0.852	0.864	0.899	0.936	0.972	0.990	0.998	1.000	*0.993*	*0.975*	*0.950*	*0.920*	*0.882*
6Y	0.833	0.846	0.881	0.919	0.959	0.981	0.993	0.999	1.000	*0.994*	*0.979*	*0.954*	*0.922*
7Y	0.816	0.829	0.864	0.904	0.946	0.972	0.987	0.995	0.999	1.000	*0.994*	*0.979*	*0.953*
8Y	0.800	0.815	0.849	0.889	0.934	0.962	0.980	0.990	0.996	0.999	1.000	*0.994*	*0.978*
9Y	0.787	0.802	0.835	0.876	0.922	0.952	0.972	0.985	0.992	0.997	0.999	1.000	*0.994*
10Y	0.774	0.789	0.822	0.863	0.911	0.943	0.964	0.978	0.988	0.994	0.997	0.999	1.000

Table A.1: Correlation of yields in levels and first differences.

A.3 Empirical Weights of Principal Components

Figures A.1 to A.11 are based on the regression results described in section 2.4.1. The figures show the coefficients (factor loadings) over time of the First and Second Principal Component, i.e. of their empirical counterparts (the ten-year rate and the spread between the ten-year and three-month rate).

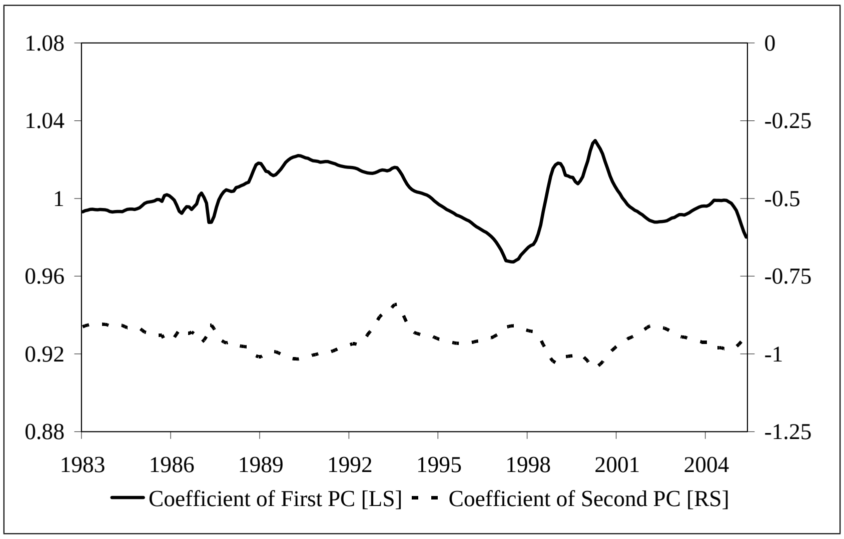

Figure A.1: Time series of factor loadings of the First and Second Principal Component explaining the six-month interest rate.

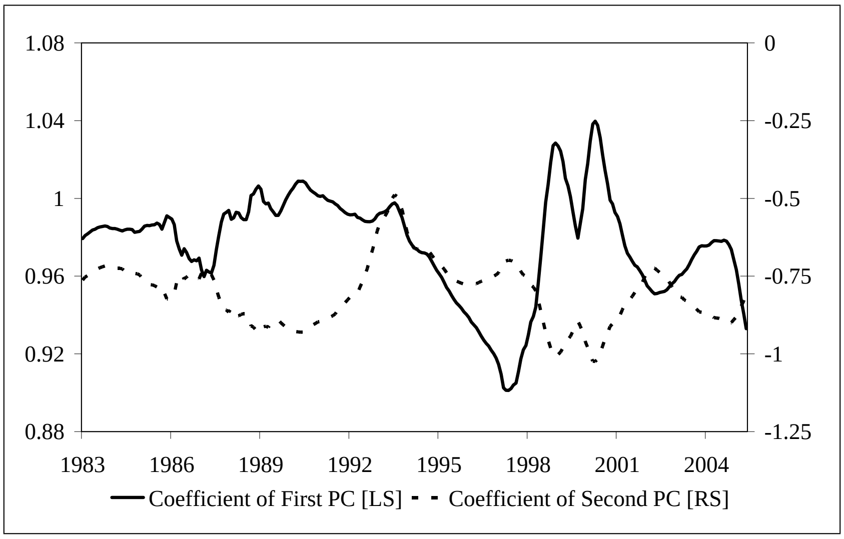

Figure A.2: Time series of factor loadings of the First and Second Principal Component explaining the one-year interest rate.

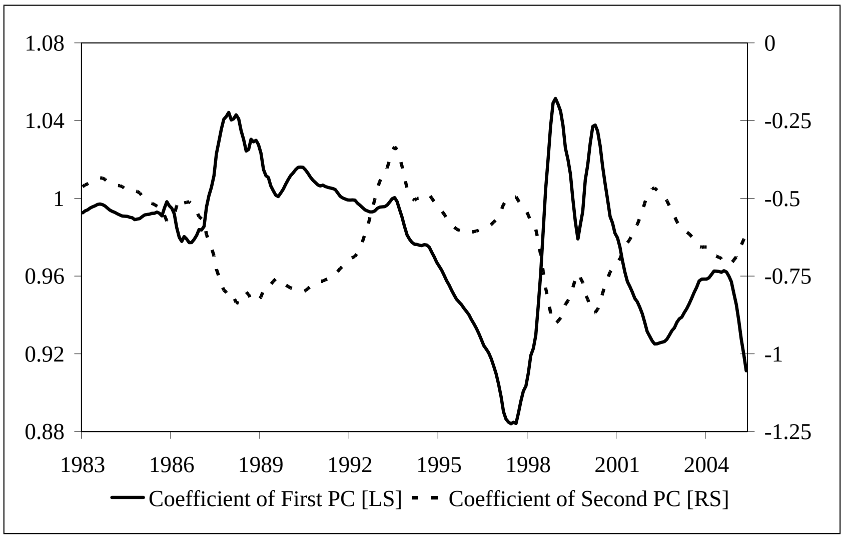

Figure A.3: Time series of factor loadings of the First and Second Principal Component explaining the two-year interest rate.

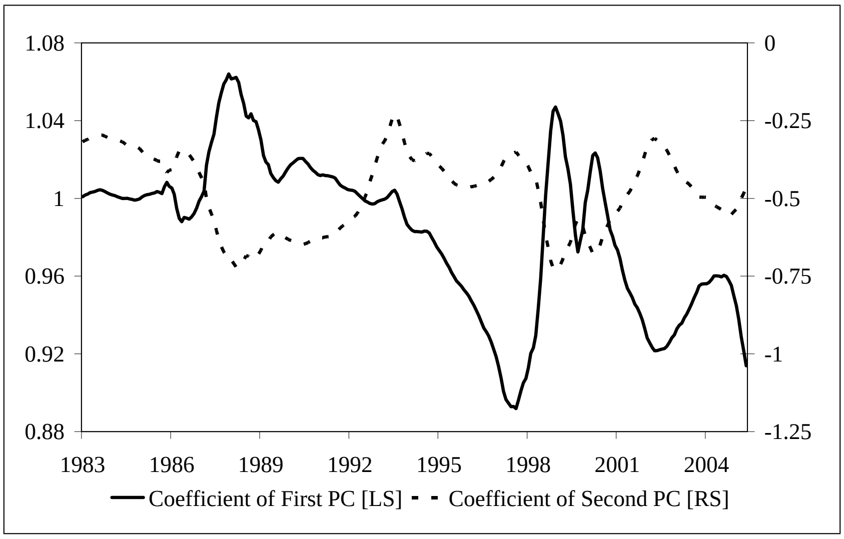

Figure A.4: Time series of factor loadings of the First and Second Principal Component explaining the three-year interest rate.

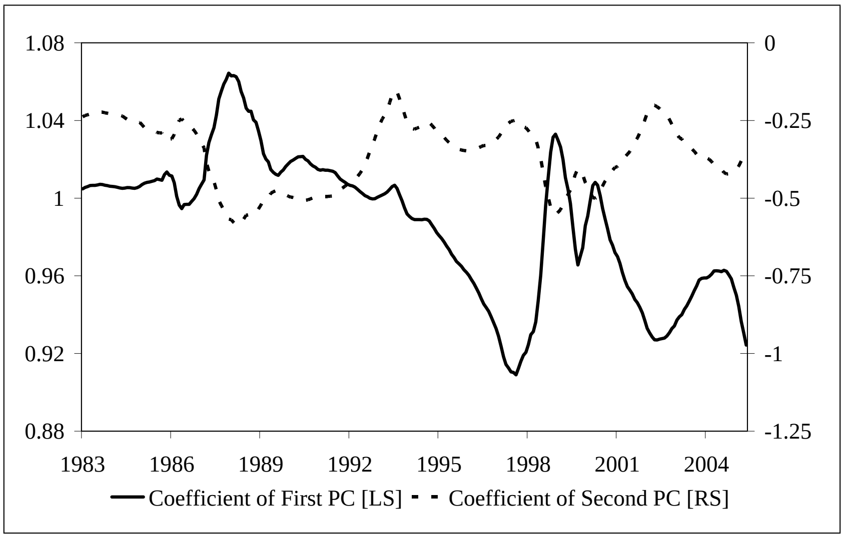

Figure A.5: Time series of factor loadings of the First and Second Principal Component explaining the four-year interest rate.

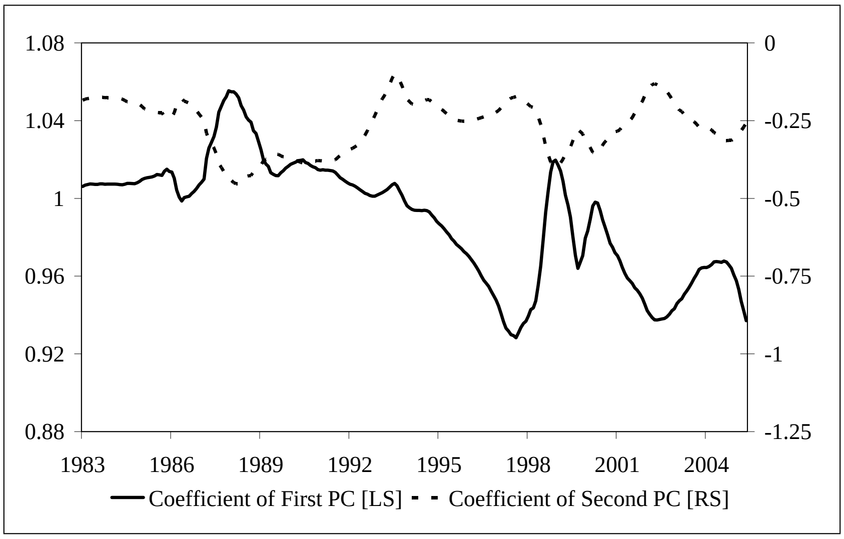

Figure A.6: Time series of factor loadings of the First and Second Principal Component explaining the five-year interest rate.

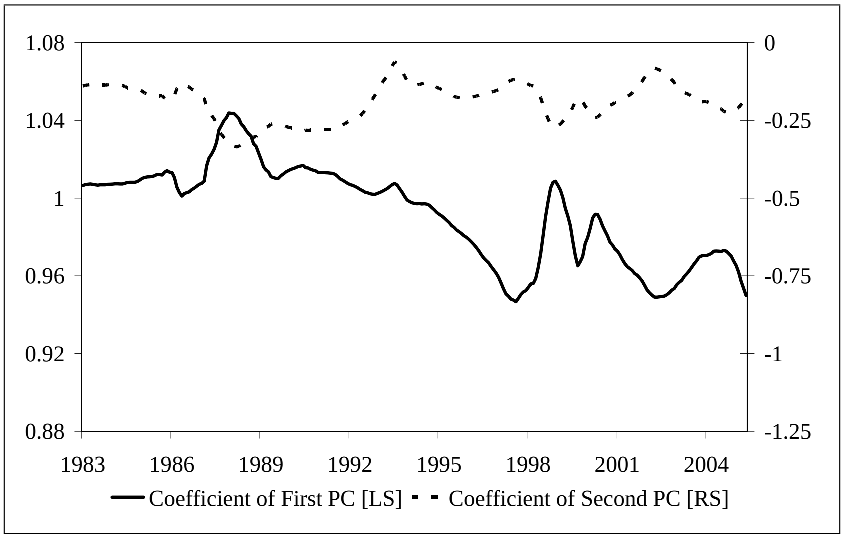

Figure A.7: Time series of factor loadings of the First and Second Principal Component explaining the six-year interest rate.

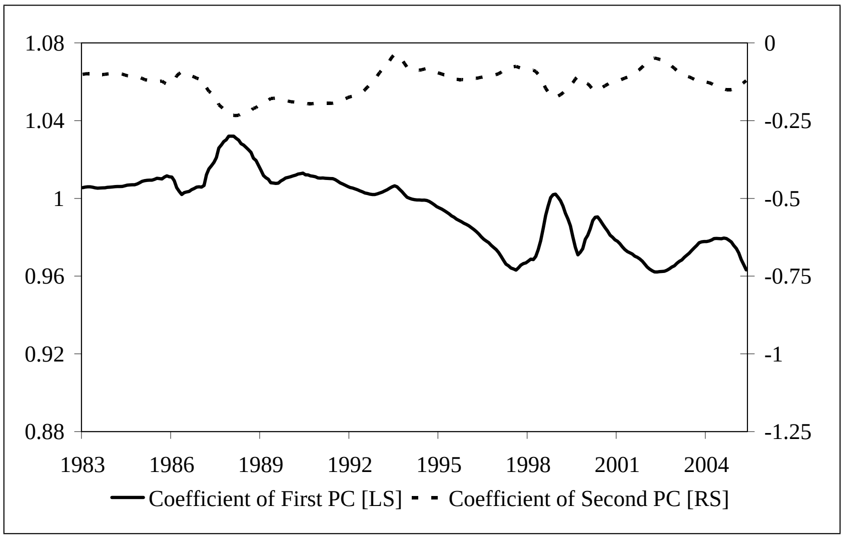

Figure A.8: Time series of factor loadings of the First and Second Principal Component explaining the seven-year interest rate.

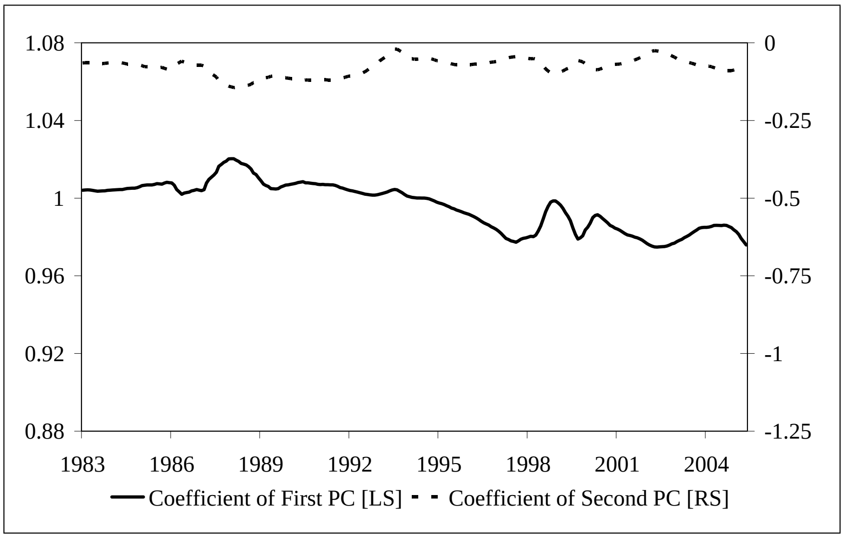

Figure A.9: Time series of factor loadings of the First and Second Principal Component explaining the eight-year interest rate.

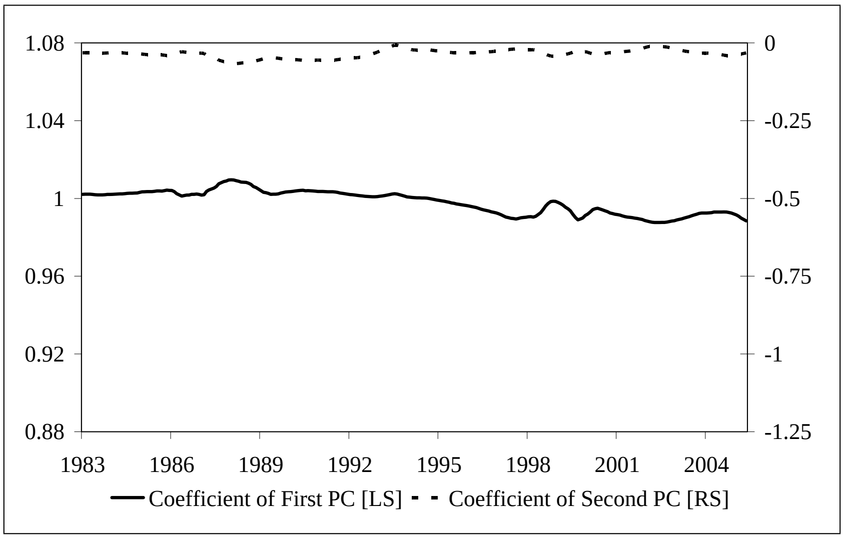

Figure A.10: Time series of factor loadings of the First and Second Principal Component explaining the nine-year interest rate.

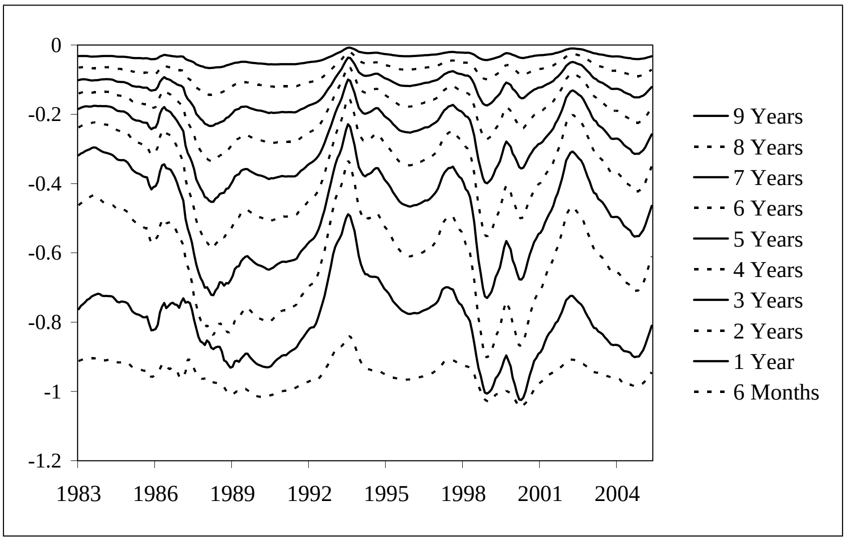

Figure A.11: Coefficients of the Second Principal Component for different time to maturities.

A.4 Parameter Stability

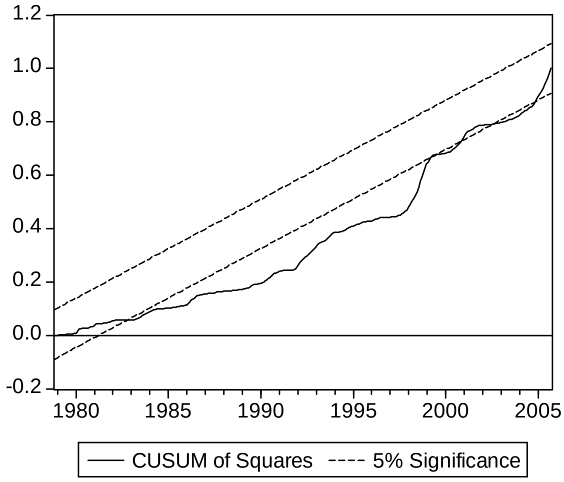

Figure A.12: Cusum of squares test for regression 2.17.

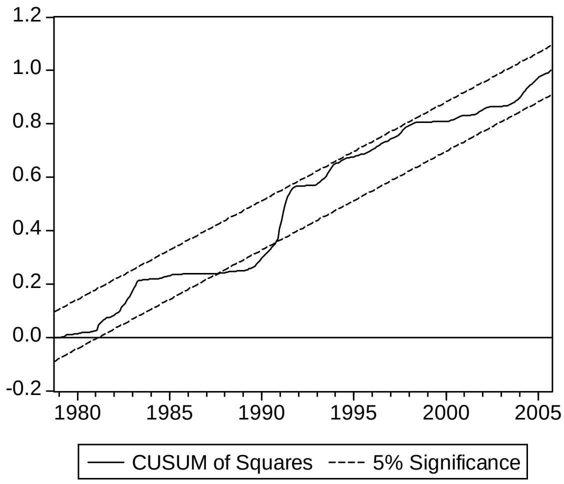

Figure A.13: Cusum of squares test for regression 2.26.

A.5 Unit Root Tests

In the following tables, c denotes a constant included in the Augmented-Dickey-Fuller test, t a trend and a constant included and n nothing included, whereas 1 and 4 denote the lag length. In table A.2, all interest rates are tested for stationarity between July 1978 and October 2005. The null hypothesis of non-stationarity cannot be rejected for any of the interest rates, because the test statistics are smaller than the corresponding critical values at the 5% level.

Maturity	c,1	c,4	t,1	t,4	n,1	n,4
1 month	-1.06	-1.77	-2.40	-2.94	-0.66	-0.89
3 months	-1.41	-1.77	-2.69	-2.98	-0.77	-0.89
6 months	-1.60	-1.81	-2.86	-3.04	-0.83	-0.89
1 year	-1.44	-1.63	-2.84	-2.99	-0.76	-0.81
2 years	-1.40	-1.44	-2.99	-3.02	-0.78	-0.78
3 years	-1.33	-1.34	-3.10	-3.10	-0.77	-0.76
4 years	-1.26	-1.27	-3.18	-3.18	-0.75	-0.75
5 years	-1.18	-1.21	-3.23	-3.24	-0.74	-0.74
6 years	-1.12	-1.15	-3.27	-3.28	-0.74	-0.74
7 years	-1.05	-1.10	-3.29	-3.30	-0.73	-0.73
8 years	-1.00	-1.05	-3.30	-3.32	-0.73	-0.73
9 years	-0.95	-1.01	-3.31	-3.35	-0.74	-0.74
10 years	-0.91	-0.97	-3.32	-3.36	-0.74	-0.74
Critical Value (5%)	-2.87	-2.87	-3.42	-3.42	-1.94	-1.94

Table A.2: Unit root test for stationarity of interest rates.

In table A.3, the macroeconomic data is tested for stationarity. With some exceptions for the Ifo-Index, the unit root tests display that the macroeconomic time series are non-stationary.

Variable	c,1	c,4	t,1	t,4	n,1	n,4
3M	-1.41	-1.77	-2.69	-2.98	-0.77	-0.89
Ifo-Index	-2.23	-3.36	-2.16	-3.29	-2.22	-3.36
CPI	-1.82	-2.22	-2.40	-2.91	-1.19	-1.32
Critical Value (5%)	-2.87	-2.87	-3.42	-3.42	-1.94	-1.94

Table A.3: Unit root test for stationarity of macroeconomic time series.

Table A.4 presents unit root tests for the time series used in the test for cointegration in sections 2.6.2 and 2.6.3, i.e. the time series of realized macroeconomic volatility and t-values. With only a few exceptions, the null hypothesis of non-stationarity of the macroeconomic time series, of their volatilities and of the t-values cannot be rejected. Hence, the findings suggest that the time series are appropriate to be used in the test for cointegration by Banerjee et al. (1998).

Variable	c,1	c,4	t,1	t,4	n,1	n,4
vola(3M)	-1.34	-0.79	-2.91	-1.77	-1.20	-1.58
vola(Ifo)	-3.40	-1.99	-3.97	-2.36	-1.42	-1.18
vola(CPI)	-1.44	-0.89	-2.25	-1.89	-1.20	-0.99
tvalue(3M,long)	-2.25	-2.31	-2.32	-2.42	-1.22	-1.22
tvalue(Ifo,long)	-2.74	-2.20	-2.61	-2.06	-2.47	-1.99
tvalue(CPI,long)	-3.19	-2.78	-3.19	-2.78	-2.97	-2.57
tvalue(Ifo,short)	-3.65	-3.16	-3.65	-3.12	-3.65	-3.16
tvalue(CPI,short)	-2.65	-2.68	-2.76	-2.81	-1.84	-1.79
Critical Value (5%)	-2.87	-2.87	-3.43	-3.43	-1.94	-1.94

Table A.4: Unit root test for stationarity of realized macroeconomic volatility and of time series of t-values.

Appendix B

Macroeconomic News and the Yield Curve

B.1 Descriptive Statistics

B.1.1 Interest Rate Data

Descriptive statistics of the interest rate data described in section 3.6 is presented in table B.1 for the level of interest rates and in table B.2 for the daily percentage change of the interest rate data. S denotes the slope of the yield curve, which is defined as $10Y - 1Y$ and the curvature C is defined as $2 \cdot 10Y - 5Y - 1Y$. The number of observations is 2642 for the daily data between 31 October 1996 and 15 December 2006.[1]

Maturity	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	S	C
Mean	3.22	3.41	3.62	3.83	3.97	4.15	4.29	4.41	4.48	4.52	1.30	-2.05
Median	3.24	3.46	3.63	3.76	3.86	4.04	4.20	4.34	4.43	4.47	1.34	-2.10
Maximum	5.19	5.30	5.32	5.37	5.34	5.45	5.62	5.90	6.03	6.04	2.81	0.13
Minimum	1.86	1.89	2.08	2.32	2.47	2.63	2.75	2.85	2.95	3.02	-0.04	-4.32
Std. Dev.	0.82	0.81	0.78	0.76	0.74	0.75	0.76	0.75	0.74	0.73	0.66	1.08
Skewness	0.36	0.18	0.06	-0.03	-0.05	-0.04	-0.04	-0.02	0.01	0.05	-0.04	0.11
Kurtosis	2.43	2.12	1.99	1.86	1.76	1.75	1.79	1.85	1.96	2.01	2.35	2.20
Jarque-Bera	95	98	113	144	170	171	162	145	120	110	48	76

Table B.1: Descriptive statistics of the level of interest rates.

daily change [%]	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	S	C
Mean	0.01	0.01	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.05	-0.80
Median	0.00	-0.02	-0.03	-0.03	-0.03	-0.04	-0.03	-0.03	-0.02	-0.03	-0.15	-0.14
Maximum	6.31	8.74	8.45	6.71	6.34	5.75	5.33	5.24	5.65	4.99	1100	400
Minimum	-4.47	-5.75	-5.67	-5.10	-5.00	-4.31	-4.02	-3.86	-3.95	-3.93	-1500	-1900
Std. Dev.	0.98	1.29	1.25	1.21	1.16	1.07	1.01	0.96	0.93	0.89	46.83	51.16
Skewness	0.74	0.65	0.71	0.54	0.56	0.51	0.50	0.53	0.49	0.49	-1.86	-24.60
Kurtosis	8.09	6.81	6.92	5.69	5.77	5.02	4.93	5.16	5.30	5.08	635.96	852.24
Jarque-Bera	3086	1787	1914	925	984	563	518	641	687	581	4E+07	8E+07

Table B.2: Descriptive statistics of daily percentage changes of interest rates.

Both the level and the daily percentage change of the interest rates are not normally distributed. They have a skewness different from 0 and the kurtosis is smaller than 3 for the level of interest rates and larger than 3 for the first difference of interest rates.

[1] In table B.2, the S and C series only have 2641 observations.

Accordingly, all p-values of the Jarque-Bera test for normality of the level of interest rates and the daily percentage change of the interest rates are 0.000.

B.1.2 Data of Surprises in Macroeconomic Announcements

The following tables present descriptive statistics of surprises of the macroeconomic indicators for Germany (tables B.3 and B.4), for the Eurozone (tables B.5 and B.6) and for the United States (tables B.7 to B.10).

Indicator	Cur. Acc.	Exp.	GDP qoq	GDP yoy	Ord. mom	Ord. yoy	Prod. mom	Prod. yoy	Ret. mom	Ret. yoy	Tra. Bal.
Mean	0.29	0.23	-0.09	-0.21	0.10	-0.11	-0.18	0.11	-0.28	-0.25	0.26
Median	0.19	0.19	0.00	-0.03	0.09	0.23	-0.10	0.08	-0.23	-0.14	0.05
Maximum	2.24	2.06	3.17	0.68	2.98	1.24	2.49	2.17	2.70	3.55	2.75
Minimum	-1.61	-2.10	-2.53	-5.08	-1.82	-2.40	-2.42	-2.59	-2.64	-3.28	-2.05
Std. Dev.	1.01	1.02	1.01	1.02	1.01	1.03	1.00	1.03	1.01	1.00	1.01
Skewness	0.23	-0.25	0.51	-4.38	0.37	-0.68	-0.05	-0.64	0.32	0.09	0.25
Kurtosis	2.06	2.56	5.07	21.60	2.66	2.69	2.65	4.14	3.35	4.69	2.76
Jarque-Bera	2.57	0.63	8.19	457.83	2.66	1.56	0.62	2.31	2.21	13.91	0.71
Observations	56	34	37	26	95	19	114	19	98	115	55

Table B.3: Descriptive statistics of surprises of German indicators (1/2).

Indicator	Une. Rate	Unem-ploy.	CPI mom	CPI yoy	Imp. Pr. mom	Imp. Pr. yoy	PPI mom	PPI yoy	Ifo-Ind.	ZEW-Ind.
Mean	-0.19	-0.14	0.01	0.05	0.09	0.10	0.17	0.17	0.36	-0.15
Median	0.00	-0.12	0.00	0.00	0.21	0.00	0.00	0.00	0.35	-0.16
Maximum	2.59	2.73	2.12	1.62	2.70	2.84	3.22	3.20	2.26	2.35
Minimum	-3.46	-3.14	-4.77	-2.43	-3.32	-3.41	-2.42	-2.80	-1.65	-2.47
Std. Dev.	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.02	1.01
Skewness	-0.46	-0.08	-2.05	-0.20	-0.62	-0.40	0.56	0.59	0.04	0.03
Kurtosis	3.85	4.28	11.98	2.62	4.88	4.84	4.12	4.57	2.33	3.16
Jarque-Bera	6.19	6.26	191.04	0.56	18.12	14.49	12.07	18.64	0.63	0.07
Observations	96	90	47	45	86	86	116	116	33	58

Table B.4: Descriptive statistics of surprises of German indicators (2/2).

Indicator	Cur. Acc.	Exp.	GDP qoq	GDP yoy	Ord. mom	Ord. yoy	Prod. mom	Prod. yoy	Ret. sal.	Ret. ex. c.	Tra. Bal.
Mean	-0.44	-0.31	-0.21	-0.10	0.03	0.12	-0.01	0.02	-0.07	-0.16	-0.12
Median	-0.73	0.00	0.00	0.00	0.04	0.08	0.00	0.13	0.00	0.00	-0.28
Maximum	2.61	1.36	1.63	1.14	2.64	2.12	1.96	2.53	1.76	2.34	1.97
Minimum	-1.39	-2.27	-3.27	-2.27	-2.22	-1.45	-2.18	-1.73	-2.73	-2.34	-1.76
Std. Dev.	1.03	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.03
Skewness	1.63	-0.22	-1.06	-0.59	0.10	0.27	0.07	0.18	-0.67	-0.26	0.57
Kurtosis	5.68	2.17	5.34	2.75	3.68	2.11	2.42	2.76	3.11	2.85	2.47
Jarque-Bera	11.85	0.59	9.55	1.42	0.69	1.44	0.99	0.53	4.70	0.77	1.11
Observations	16	16	23	23	33	32	67	66	62	62	17

Table B.5: Descriptive statistics of surprises of European indicators (1/2).

Indicator	Une. Rate	CPI Fl. yoy	CPI mom	CPI yoy	PPI mom	PPI yoy	Cons. Conf.	Bus. Conf.	ESI
Mean	-0.26	0.08	0.00	-0.12	-0.02	0.11	0.33	0.18	0.29
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Maximum	2.66	2.36	2.32	3.20	4.57	3.97	2.93	2.12	3.67
Minimum	-2.66	-2.36	-3.47	-1.60	-2.29	-2.38	-1.46	-2.83	-1.59
Std. Dev.	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Skewness	0.15	-0.13	-0.28	0.41	1.43	0.53	0.72	-0.36	1.23
Kurtosis	4.05	3.00	4.56	3.85	8.45	5.89	2.91	3.50	5.54
Jarque-Bera	3.85	0.17	7.62	3.99	100.99	25.28	3.60	1.37	21.32
Observations	78	58	67	68	64	64	42	43	41

Table B.6: Descriptive statistics of surprises of European indicators (2/2).

Indicator	Vehi. Sal.	Ave. Earn.	Bus. Inv.	Cap. Util.	Curr. Acc.	Dur. Ord.	GDP yoy	Hou. Per.	Hou. Sta.	Prod. mom	Ord.
Mean	0.26	-0.09	0.15	-0.01	0.02	0.02	0.01	0.23	0.17	-0.06	0.08
Median	0.00	0.00	0.23	0.00	-0.10	0.03	0.00	0.12	0.18	0.00	0.18
Maximum	3.53	2.91	2.76	2.29	2.68	3.66	4.58	2.62	2.73	2.48	3.37
Minimum	-1.90	-2.18	-3.67	-2.62	-1.60	-2.78	-2.06	-1.47	-2.70	-3.19	-3.37
Std. Dev.	1.01	1.00	1.00	1.00	1.01	1.00	1.01	1.01	1.00	1.00	1.00
Skewness	0.97	0.10	-0.52	0.03	0.66	0.49	2.20	0.27	-0.22	-0.05	-0.24
Kurtosis	4.44	2.73	4.27	2.53	2.79	5.21	12.28	2.47	3.14	2.79	4.34
Jarque-Bera	11.7	0.47	12.7	1.13	2.64	26.6	167	1.24	0.93	0.28	10.2
Observations	48	102	114	120	35	109	38	52	105	121	122

Table B.7: Descriptive statistics of surprises of US indicators (1/4).

Indicator	Ini. Clai.	Pay-rolls	Pers. Exp.	Pers. Inc.	Prod.	Ret.	Ret. ex. a.	Tra. Bal.	Une.-rate	Unit Lab. Co.	CPI mom
Mean	-0.01	-0.21	0.02	0.18	0.16	0.08	0.06	-0.08	-0.21	0.01	-0.12
Median	0.00	-0.16	0.00	0.00	0.26	0.00	0.00	-0.14	0.00	-0.22	0.00
Maximum	4.43	2.43	4.79	6.72	1.83	5.91	2.96	2.81	2.26	2.44	2.45
Minimum	-3.93	-3.15	-4.25	-1.92	-2.36	-2.05	-2.32	-3.58	-2.26	-1.99	-2.45
Std. Dev.	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.00	1.00	1.02	1.00
Skewness	0.21	-0.14	0.20	2.32	-0.55	2.94	0.21	-0.11	-0.13	0.36	0.03
Kurtosis	5.12	3.31	9.50	17.28	2.80	18.18	3.48	4.19	2.66	3.24	3.21
Jarque-Bera	95.9	0.87	210	1136	1.88	740	1.13	7.45	0.90	0.74	0.24
Observations	494	120	119	121	36	67	67	121	121	30	120

Table B.8: Descriptive statistics of surprises of US indicators (2/4).

Indicator	CPI yoy	PCE core	PPI mom	PPI yoy	Cons. Conf.	Emp. St. I.	ISM mfg	ISM nmfg	Lead. Ind.	Phil. Ind.	PMI Chic.
Mean	-0.06	0.21	-0.03	-0.10	0.08	0.18	0.01	0.17	0.05	-0.06	0.10
Median	0.00	0.00	0.00	0.00	0.11	0.24	-0.18	0.21	0.00	-0.08	0.12
Maximum	2.15	2.32	2.80	3.02	3.17	1.86	3.71	2.53	3.59	2.23	2.32
Minimum	-2.15	-2.32	-2.80	-3.78	-2.64	-2.25	-2.36	-2.04	-2.15	-3.46	-2.89
Std. Dev.	1.00	1.02	1.00	1.00	1.00	1.01	1.00	1.01	1.00	1.00	1.00
Skewness	0.31	-0.37	-0.01	-0.11	0.24	-0.48	0.65	0.06	0.95	-0.25	-0.22
Kurtosis	2.69	3.05	4.37	5.14	3.67	2.70	3.93	2.40	4.75	3.23	2.93
Jarque-Bera	2.32	0.60	8.40	23.06	3.39	2.15	12.92	1.51	32.80	1.52	0.98
Observations	118	27	108	120	118	50	122	95	118	119	118

Table B.9: Descriptive statistics of surprises of US indicators (3/4).

Indicator	Help Wa. I.	Uni. o. Mich.
Mean	-0.49	-0.49
Median	-0.66	-0.05
Maximum	2.63	1.73
Minimum	-2.63	-4.75
Std. Dev.	1.01	1.01
Skewness	0.54	-2.01
Kurtosis	4.05	7.67
Jarque-Bera	4.44	143.95
Observations	47	91

Table B.10: Descriptive statistics of surprises of US indicators (4/4).

B.2 Estimation Results

The following tables present the estimation results of the event study for the various time to maturities and for the slope and curvature of the yield curve. Tables B.11 to B.13 show the results for German indicators, tables B.14 and B.15 the results for Eurozone indicators and tables B.16 to B.19 the results for the US indicators.

Germany	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Current Account	56	-0.170	-0.076	-0.041	-0.022	0.065	0.024
		(0.287)	(0.769)	(0.859)	(0.922)	(0.784)	(0.909)
		0.021	0.015	0.021	0.032	0.475	-16.273
		(0.912)	(0.931)	(0.896)	(0.838)	(0.386)	(0.411)
Exports	34	0.158	0.055	0.224	0.212	0.188	0.140
		(0.301)	(0.826)	(0.297)	(0.332)	(0.385)	(0.485)
		0.131	0.109	0.109	0.121	-0.463	37.773
		(0.481)	(0.531)	(0.500)	(0.450)	(0.508)	(0.147)
GDP, qoq	37	0.142	0.170	0.074	0.116	0.138	0.122
preliminary		(0.126)	(0.228)	(0.627)	(0.408)	(0.277)	(0.313)
		0.138	0.103	0.169	0.088	0.037	2.976
		(0.248)	(0.343)	(0.130)	(0.460)	(0.993)	(0.861)
GDP, yoy	26	-0.006	-0.143	-0.167	-0.157	-0.145	-0.149
preliminary		(0.949)	(0.375)	(0.291)	(0.292)	(0.332)	(0.291)
		-0.127	-0.132	-0.141	-0.099	0.317	2.124
		(0.353)	(0.307)	(0.268)	(0.466)	(0.959)	(0.932)
Industrial	95	0.012	0.064	0.144	0.126	0.138	0.109
Orders, mom		(0.896)	(0.562)	(0.204)	(0.249)	(0.208)	(0.293)
		0.133	0.141	0.144	0.134	2.394	-8.196
		(0.180)	(0.148)	(0.108)	(0.149)	(0.276)	(0.589)
Industrial	19	0.139	0.108	0.120	0.113	0.113	0.116
Orders, yoy		(0.329)	(0.609)	(0.561)	(0.566)	(0.575)	(0.536)
		0.137	0.139	0.164	0.156	3.020	-5.754
		(0.466)	(0.438)	(0.318)	(0.345)	(0.719)	(0.459)
Industrial	114	-0.025	0.029	-0.005	-0.008	-0.041	-0.041
Production, mom		(0.799)	(0.817)	(0.970)	(0.949)	(0.706)	(0.700)
		-0.039	0.012	0.025	0.039	1.065	0.507
		(0.694)	(0.900)	(0.780)	(0.649)	(0.312)	(0.960)
Industrial	19	-0.914	-1.353	-1.073	-0.864	-0.634	-0.619
Production, yoy		(0.072)	(0.135)	(0.238)	(0.368)	(0.524)	(0.517)
		-0.462	-0.534	-0.531	-0.430	-5.919	-190.051
		(0.621)	(0.559)	(0.561)	(0.636)	(0.787)	(0.421)

Table B.11: Estimation results for German indicators (1/3).

Germany (cont'd)	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Retail Sales, mom	98	0.178	0.174	0.139	0.128	0.173	0.162
		(0.131)	(0.289)	(0.359)	(0.347)	(0.149)	(0.129)
		0.152	0.135	0.144	0.110	0.087	-3.120
		(0.128)	(0.150)	(0.104)	(0.209)	(0.918)	(0.625)
Retail Sales, yoy	115	0.038	0.102	0.058	0.072	0.112	0.084
		(0.702)	(0.468)	(0.656)	(0.545)	(0.281)	(0.369)
		0.096	0.103	0.103	0.118	0.982	-6.446
		(0.274)	(0.212)	(0.185)	(0.126)	(0.395)	(0.228)
Trade Balance	55	0.243	0.021	0.138	0.078	0.017	0.064
		(0.121)	(0.933)	(0.539)	(0.729)	(0.942)	(0.754)
		0.049	0.052	0.053	0.050	-0.413	-26.568
		(0.793)	(0.765)	(0.747)	(0.755)	(0.460)	(0.191)
Unemployed	90	-0.135	-0.197	-0.185	-0.122	-0.139	-0.161
		(0.368)	(0.361)	(0.364)	(0.544)	(0.491)	(0.372)
		-0.114	-0.095	-0.076	-0.076	2.096	-65.932
		(0.495)	(0.562)	(0.612)	(0.601)	(0.281)	(0.017)
Unemployment Rate	96	0.212	0.189	0.159	0.164	0.135	0.142
		(0.131)	(0.339)	(0.395)	(0.375)	(0.464)	(0.388)
		0.110	0.090	0.083	0.071	-0.827	71.361
		(0.471)	(0.550)	(0.544)	(0.591)	(0.634)	(0.004)
CPI, mom	47	0.148	0.128	0.124	0.097	0.063	0.098
		(0.289)	(0.516)	(0.511)	(0.616)	(0.775)	(0.602)
		0.060	0.054	0.042	0.036	2.366	6.203
		(0.733)	(0.750)	(0.798)	(0.824)	(0.653)	(0.931)
CPI, yoy	45	-0.027	0.122	0.173	0.193	0.251	0.202
		(0.855)	(0.557)	(0.381)	(0.341)	(0.277)	(0.303)
		0.213	0.208	0.211	0.200	1.060	7.762
		(0.250)	(0.240)	(0.219)	(0.231)	(0.751)	(0.920)

Table B.12: Estimation results for German indicators (2/3).

Germany (cont'd)	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Import Prices, mom	86	-0.534	-0.787	-0.312	0.083	-0.116	0.181
		(0.462)	(0.435)	(0.738)	(0.930)	(0.893)	(0.830)
		0.269	0.256	0.219	0.176	-7.687	-21.835
		(0.737)	(0.736)	(0.760)	(0.801)	(0.598)	(0.621)
Import Prices, yoy	86	0.359	0.516	0.071	-0.300	-0.108	-0.366
		(0.621)	(0.609)	(0.940)	(0.750)	(0.901)	(0.664)
		-0.415	-0.383	-0.331	-0.284	12.667	26.730
		(0.605)	(0.614)	(0.645)	(0.684)	(0.386)	(0.546)
PPI, mom	116	0.238	-0.196	-0.259	-0.130	-0.299	-0.221
		(0.545)	(0.689)	(0.601)	(0.795)	(0.513)	(0.627)
		-0.211	-0.211	-0.226	-0.190	6.341	115.768
		(0.624)	(0.607)	(0.562)	(0.614)	(0.216)	(0.023)
PPI, yoy	116	-0.283	0.290	0.388	0.286	0.431	0.359
		(0.480)	(0.560)	(0.441)	(0.574)	(0.353)	(0.438)
		0.371	0.355	0.383	0.352	-5.224	-134.578
		(0.397)	(0.395)	(0.332)	(0.356)	(0.315)	(0.010)
Ifo-Index	33	0.591	0.729	0.717	0.668	0.617	0.567
		(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.003)
		0.511	0.465	0.427	0.397	-0.718	17.283
		(0.004)	(0.006)	(0.009)	(0.012)	(0.544)	(0.345)
ZEW-Index	58	0.234	0.534	0.486	0.467	0.442	0.367
		(0.040)	(0.003)	(0.006)	(0.013)	(0.016)	(0.026)
		0.356	0.355	0.333	0.326	-1.054	79.977
		(0.019)	(0.014)	(0.023)	(0.016)	(0.825)	(0.068)

Table B.13: Estimation results for German indicators (3/3).

Eurozone	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Current	16	-0.366	-0.564	-0.824	-0.613	-0.540	-0.319
Account		(0.085)	(0.118)	(0.035)	(0.072)	(0.101)	(0.347)
		-0.284	-0.265	-0.234	-0.208	0.040	-33.756
		(0.396)	(0.419)	(0.463)	(0.504)	(0.969)	(0.013)
Labour Cost	16	-0.217	-0.446	-0.414	-0.521	-0.530	-0.539
Index		(0.190)	(0.069)	(0.078)	(0.051)	(0.054)	(0.042)
		-0.487	-0.463	-0.437	-0.396	-0.633	31.734
		(0.053)	(0.059)	(0.071)	(0.086)	(0.163)	(0.151)
GDP, qoq	23	0.255	0.349	0.335	0.352	0.289	0.271
final		(0.234)	(0.252)	(0.279)	(0.281)	(0.398)	(0.415)
		0.274	0.232	0.223	0.187	0.306	-24.878
		(0.384)	(0.459)	(0.467)	(0.531)	(0.907)	(0.476)
GDP, yoy	23	-0.315	-0.516	-0.503	-0.519	-0.538	-0.463
final		(0.185)	(0.132)	(0.148)	(0.155)	(0.162)	(0.212)
		-0.512	-0.489	-0.490	-0.443	-3.245	41.256
		(0.148)	(0.164)	(0.155)	(0.183)	(0.271)	(0.291)
Industrial	33	0.027	0.044	-0.139	0.046	0.081	0.156
Orders, mom		(0.891)	(0.883)	(0.647)	(0.872)	(0.769)	(0.546)
		0.157	0.165	0.169	0.174	1.091	-1.907
		(0.515)	(0.474)	(0.446)	(0.443)	(0.393)	(0.840)
Industrial	32	-0.407	-0.685	-0.484	-0.533	-0.520	-0.545
Orders, yoy		(0.058)	(0.035)	(0.133)	(0.081)	(0.078)	(0.049)
		-0.497	-0.497	-0.474	-0.388	-1.709	-5.760
		(0.055)	(0.045)	(0.046)	(0.106)	(0.187)	(0.539)
Industrial	67	0.077	0.111	0.071	0.069	0.070	0.038
Production, mom		(0.583)	(0.577)	(0.717)	(0.715)	(0.705)	(0.825)
		0.021	-0.006	0.011	0.007	2.865	-19.779
		(0.894)	(0.969)	(0.942)	(0.957)	(0.544)	(0.464)
Industrial	66	-0.110	-0.192	-0.137	-0.184	-0.212	-0.186
Production, yoy		(0.432)	(0.332)	(0.481)	(0.327)	(0.250)	(0.282)
		-0.180	-0.183	-0.162	-0.188	2.429	22.968
		(0.265)	(0.216)	(0.283)	(0.162)	(0.605)	(0.393)
Retail	62	-0.092	-0.252	-0.277	-0.359	-0.340	-0.362
Sales, mom		(0.744)	(0.563)	(0.483)	(0.343)	(0.337)	(0.289)
		-0.405	-0.417	-0.409	-0.441	-1.969	-22.419
		(0.201)	(0.171)	(0.154)	(0.106)	(0.526)	(0.021)
Retail	62	0.056	0.348	0.317	0.417	0.404	0.386
Sales, yoy		(0.849)	(0.454)	(0.452)	(0.299)	(0.284)	(0.289)
		0.413	0.409	0.406	0.453	2.428	22.533
		(0.220)	(0.206)	(0.181)	(0.118)	(0.455)	(0.030)

Table B.14: Estimation results for European indicators (1/2).

Eurozone (cont'd)	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Trade Balance	17	-0.321	-0.482	-0.510	-0.518	-0.517	-0.465
		(0.238)	(0.262)	(0.245)	(0.250)	(0.258)	(0.276)
		-0.386	-0.403	-0.330	-0.335	1.556	-16.657
		(0.337)	(0.290)	(0.364)	(0.354)	(0.350)	(0.355)
Unemployment	78	0.051	0.115	0.098	0.098	0.069	0.079
Rate		(0.631)	(0.417)	(0.497)	(0.460)	(0.568)	(0.473)
		0.074	0.074	0.072	0.062	0.701	-2.263
		(0.470)	(0.447)	(0.435)	(0.483)	(0.512)	(0.694)
CPI, yoy	58	0.012	0.051	0.000	-0.017	-0.040	0.025
Flash Estimate		(0.928)	(0.786)	(0.998)	(0.916)	(0.783)	(0.856)
		0.014	0.021	0.019	0.030	-2.407	-0.665
		(0.917)	(0.862)	(0.863)	(0.778)	(0.241)	(0.938)
CPI, mom	67	0.221	0.422	0.316	0.438	0.431	0.309
final		(0.201)	(0.057)	(0.192)	(0.029)	(0.030)	(0.126)
		0.345	0.347	0.345	0.360	0.625	6.890
		(0.058)	(0.046)	(0.023)	(0.023)	(0.305)	(0.857)
CPI, yoy	68	0.212	-0.080	0.078	-0.179	-0.186	0.026
final		(0.205)	(0.698)	(0.728)	(0.355)	(0.338)	(0.898)
		-0.058	-0.089	-0.161	-0.187	-0.868	-11.212
		(0.746)	(0.601)	(0.275)	(0.222)	(0.482)	(0.763)
PPI, mom	64	-0.599	-0.888	-0.811	-0.761	-0.726	-0.632
		(0.007)	(0.006)	(0.009)	(0.008)	(0.006)	(0.009)
		-0.598	-0.548	-0.504	-0.525	-1.234	7.107
		(0.007)	(0.008)	(0.009)	(0.007)	(0.138)	(0.457)
PPI, yoy	64	0.446	0.679	0.590	0.589	0.568	0.517
		(0.039)	(0.032)	(0.053)	(0.036)	(0.030)	(0.030)
		0.501	0.464	0.435	0.424	7.304	0.846
		(0.022)	(0.022)	(0.022)	(0.027)	(0.177)	(0.929)
Consumer	42	-0.014	0.128	0.529	0.456	0.172	0.212
Confidence		(0.913)	(0.500)	(0.007)	(0.015)	(0.274)	(0.152)
		0.207	0.190	0.184	0.165	1.042	-11.400
		(0.129)	(0.130)	(0.110)	(0.128)	(0.703)	(0.182)
Business	43	-0.381	-0.582	-0.356	-0.305	-0.397	-0.373
Confidence		(0.019)	(0.009)	(0.089)	(0.128)	(0.025)	(0.023)
		-0.361	-0.319	-0.273	-0.264	-0.261	-4.294
		(0.017)	(0.021)	(0.030)	(0.025)	(0.772)	(0.629)
ESI	41	0.524	0.856	0.602	0.362	0.470	0.580
		(0.002)	(0.000)	(0.007)	(0.082)	(0.010)	(0.001)
		0.543	0.483	0.430	0.423	0.491	-3.465
		(0.001)	(0.001)	(0.001)	(0.001)	(0.624)	(0.733)

Table B.15: Estimation results for European indicators (2/2).

USA	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Auto Sales	48	0.031	0.184	0.318	0.266	0.192	0.148
		(0.876)	(0.509)	(0.224)	(0.227)	(0.330)	(0.391)
		0.140	0.118	0.108	0.135	-13.490	-13.434
		(0.371)	(0.413)	(0.425)	(0.294)	(0.572)	(0.155)
Aver. Hourly	102	0.314	0.484	0.463	0.486	0.466	0.423
Earnings		(0.016)	(0.015)	(0.009)	(0.003)	(0.003)	(0.003)
		0.387	0.338	0.312	0.296	0.817	8.552
		(0.005)	(0.006)	(0.007)	(0.009)	(0.497)	(0.090)
Business	114	0.008	-0.094	-0.096	-0.069	-0.085	-0.054
Inventories		(0.938)	(0.482)	(0.427)	(0.559)	(0.510)	(0.632)
		-0.034	-0.029	-0.023	-0.005	0.055	-18.692
		(0.744)	(0.771)	(0.814)	(0.957)	(0.994)	(0.112)
Capacity	120	0.099	0.074	0.051	0.053	-0.079	0.080
Utilization		(0.415)	(0.679)	(0.792)	(0.729)	(0.642)	(0.572)
		0.041	0.046	-0.057	0.018	2.227	-11.600
		(0.752)	(0.703)	(0.641)	(0.873)	(0.064)	(0.510)
Current	35	0.213	0.218	0.107	0.246	0.222	0.207
Account		(0.334)	(0.464)	(0.721)	(0.295)	(0.329)	(0.309)
		0.179	0.168	0.143	0.139	-1.188	-29.736
		(0.323)	(0.322)	(0.387)	(0.390)	(0.428)	(0.211)
Durables	109	0.062	0.153	0.179	0.204	0.175	0.155
Orders		(0.454)	(0.165)	(0.086)	(0.065)	(0.085)	(0.113)
		0.150	0.134	0.130	0.115	1.054	-1.268
		(0.107)	(0.130)	(0.138)	(0.180)	(0.189)	(0.834)
GDP, final	38	-0.182	-0.325	-0.336	-0.307	-0.281	-0.265
		(0.417)	(0.278)	(0.238)	(0.268)	(0.272)	(0.292)
		-0.225	-0.226	-0.172	-0.155	-0.544	-4.775
		(0.337)	(0.301)	(0.400)	(0.414)	(0.519)	(0.472)
Housing	52	0.004	0.064	-0.028	0.118	0.129	0.184
Permits		(0.977)	(0.750)	(0.901)	(0.535)	(0.498)	(0.331)
		0.165	0.176	0.199	0.123	-0.553	2.331
		(0.315)	(0.236)	(0.214)	(0.380)	(0.455)	(0.846)
Housing	105	-0.067	-0.057	-0.030	-0.093	-0.096	-0.179
Starts		(0.483)	(0.631)	(0.817)	(0.411)	(0.390)	(0.100)
		-0.143	-0.118	-0.097	-0.051	0.426	-7.572
		(0.133)	(0.185)	(0.288)	(0.542)	(0.490)	(0.320)
Industrial	121	0.163	0.213	0.274	0.270	0.345	0.205
Production		(0.173)	(0.227)	(0.145)	(0.073)	(0.039)	(0.138)
		0.215	0.212	0.239	0.194	-2.058	17.417
		(0.089)	(0.077)	(0.049)	(0.079)	(0.079)	(0.314)

Table B.16: Estimation results for US indicators (1/4).

USA (cont'd)	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Industrial	122	0.083	0.086	0.124	0.117	0.086	0.165
Orders		(0.394)	(0.514)	(0.377)	(0.327)	(0.472)	(0.115)
		0.121	0.093	0.089	0.094	-0.673	20.134
		(0.210)	(0.298)	(0.298)	(0.275)	(0.532)	(0.367)
Initial	494	-0.142	-0.195	-0.184	-0.164	-0.145	-0.147
Claims		(0.005)	(0.003)	(0.004)	(0.007)	(0.017)	(0.007)
		-0.139	-0.136	-0.114	-0.114	-0.410	2.215
		(0.006)	(0.005)	(0.015)	(0.011)	(0.846)	(0.741)
Non-farm	120	0.590	0.767	0.739	0.710	0.630	0.591
Payrolls		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		0.452	0.464	0.426	0.399	-0.807	5.405
		(0.000)	(0.000)	(0.000)	(0.000)	(0.431)	(0.205)
Household	119	0.055	0.141	0.097	0.069	0.035	0.051
Expenditures		(0.576)	(0.297)	(0.426)	(0.540)	(0.720)	(0.584)
		0.072	0.027	0.063	0.078	-0.596	-1.840
		(0.403)	(0.750)	(0.406)	(0.279)	(0.590)	(0.684)
Houshold	121	0.065	0.096	0.090	0.079	0.120	0.102
Income		(0.485)	(0.450)	(0.436)	(0.462)	(0.199)	(0.254)
		0.087	0.088	0.091	0.090	1.176	2.444
		(0.289)	(0.277)	(0.209)	(0.190)	(0.252)	(0.561)
Productivity,	36	0.099	0.162	0.172	0.160	0.161	0.163
final		(0.505)	(0.408)	(0.386)	(0.411)	(0.395)	(0.350)
		0.131	0.115	0.111	0.101	3.115	10.084
		(0.428)	(0.443)	(0.450)	(0.470)	(0.090)	(0.826)
Retail Sales	67	0.306	0.527	0.545	0.558	0.430	0.477
		(0.061)	(0.046)	(0.032)	(0.027)	(0.094)	(0.032)
		0.445	0.402	0.382	0.374	-1.894	-9.720
		(0.032)	(0.042)	(0.044)	(0.040)	(0.908)	(0.832)
Retail Sales	67	-0.009	-0.077	-0.115	-0.128	0.000	-0.083
ex. autos		(0.955)	(0.770)	(0.652)	(0.612)	(0.999)	(0.711)
		-0.074	-0.061	-0.050	-0.053	23.769	34.404
		(0.722)	(0.758)	(0.791)	(0.773)	(0.159)	(0.462)
Trade	121	0.072	0.146	0.137	0.120	0.118	0.116
Balance		(0.466)	(0.174)	(0.199)	(0.231)	(0.211)	(0.180)
		0.106	0.089	0.085	0.090	-3.504	-4.323
		(0.189)	(0.248)	(0.258)	(0.214)	(0.148)	(0.566)
Unemployment	121	0.057	0.036	0.022	-0.031	-0.024	0.012
Rate		(0.613)	(0.831)	(0.887)	(0.819)	(0.855)	(0.919)
		0.014	0.017	0.028	0.028	-0.717	3.077
		(0.905)	(0.872)	(0.782)	(0.770)	(0.476)	(0.462)

Table B.17: Estimation results for US indicators (2/4).

USA (cont'd)	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Unit Labour Costs, final	30	-0.108	-0.173	-0.126	-0.071	-0.051	-0.028
		(0.441)	(0.476)	(0.612)	(0.771)	(0.831)	(0.897)
		-0.022	-0.020	-0.017	-0.010	8.327	-20.754
		(0.913)	(0.913)	(0.920)	(0.951)	(0.001)	(0.730)
CPI	120	0.067	0.093	0.045	0.083	0.057	0.062
		(0.490)	(0.515)	(0.741)	(0.519)	(0.665)	(0.616)
		0.050	0.054	0.047	0.064	-1.341	9.574
		(0.652)	(0.599)	(0.650)	(0.512)	(0.046)	(0.346)
CPI, core	118	-0.009	0.011	0.036	0.045	-0.001	-0.013
		(0.931)	(0.938)	(0.791)	(0.729)	(0.996)	(0.919)
		0.009	0.013	0.055	0.022	1.993	-8.306
		(0.938)	(0.899)	(0.599)	(0.820)	(0.021)	(0.420)
PCE, core	27	0.354	0.592	0.538	0.415	0.442	0.489
		(0.004)	(0.002)	(0.002)	(0.021)	(0.010)	(0.004)
		0.448	0.424	0.408	0.406	-5.137	-7.089
		(0.005)	(0.005)	(0.008)	(0.008)	(0.269)	(0.562)
PPI	108	-0.086	-0.100	-0.117	-0.103	-0.102	-0.073
		(0.448)	(0.487)	(0.360)	(0.414)	(0.409)	(0.529)
		-0.061	-0.051	-0.071	-0.030	1.605	6.642
		(0.577)	(0.618)	(0.473)	(0.758)	(0.381)	(0.243)
PPI, core	120	0.099	0.203	0.201	0.184	0.193	0.172
		(0.359)	(0.124)	(0.088)	(0.114)	(0.094)	(0.108)
		0.137	0.130	0.184	0.109	4.385	-9.879
		(0.176)	(0.171)	(0.047)	(0.222)	(0.008)	(0.151)
Conference Board	118	0.216	0.323	0.312	0.310	0.281	0.276
		(0.006)	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)
		0.243	0.229	0.225	0.218	0.542	2.622
		(0.005)	(0.006)	(0.009)	(0.006)	(0.680)	(0.551)
Empire State	50	-0.014	0.355	0.338	0.116	0.325	0.287
		(0.937)	(0.121)	(0.119)	(0.650)	(0.138)	(0.139)
		0.247	0.230	0.189	0.206	-4.563	8.220
		(0.176)	(0.192)	(0.279)	(0.210)	(0.353)	(0.866)
ISM mfg	122	0.433	0.620	0.634	0.675	0.675	0.654
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		0.638	0.599	0.603	0.555	-8.202	-5.247
		(0.000)	(0.000)	(0.000)	(0.000)	(0.398)	(0.279)
ISM non-mfg	95	0.170	0.264	0.217	0.269	0.294	0.313
		(0.131)	(0.110)	(0.169)	(0.053)	(0.026)	(0.010)
		0.311	0.307	0.296	0.285	-0.481	48.511
		(0.005)	(0.005)	(0.003)	(0.003)	(0.715)	(0.053)

Table B.18: Estimation results for US indicators (3/4).

USA (cont'd)	Obs.	beta(1Y) p-value beta(7Y) p-value	beta(2Y) p-value beta(8Y) p-value	beta(3Y) p-value beta(9Y) p-value	beta(4Y) p-value beta(10Y) p-value	beta(5Y) p-value beta(S) p-value	beta(6Y) p-value beta(C) p-value
Leading Indicator	118	-0.016	0.001	-0.018	0.015	0.032	0.030
		(0.819)	(0.995)	(0.853)	(0.864)	(0.711)	(0.726)
		0.043	0.031	0.042	0.035	0.332	-1.326
		(0.596)	(0.696)	(0.589)	(0.626)	(0.783)	(0.914)
Phily Fed Index	119	0.044	0.101	0.043	0.081	0.054	0.064
		(0.607)	(0.378)	(0.732)	(0.457)	(0.629)	(0.515)
		0.035	0.034	0.071	0.066	0.126	9.062
		(0.700)	(0.697)	(0.411)	(0.417)	(0.787)	(0.420)
PMI Chicago	118	0.255	0.433	0.392	0.417	0.413	0.336
		(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		0.307	0.273	0.264	0.250	1.868	0.486
		(0.000)	(0.001)	(0.001)	(0.001)	(0.076)	(0.912)
Help Wanted Index	47	0.209	0.261	0.315	0.338	0.338	0.291
		(0.350)	(0.406)	(0.252)	(0.195)	(0.175)	(0.206)
		0.292	0.266	0.272	0.271	-0.312	-9.657
		(0.167)	(0.174)	(0.138)	(0.132)	(0.885)	(0.236)
University of Michigan, final	91	0.108	0.167	0.127	0.109	0.073	0.070
		(0.348)	(0.313)	(0.399)	(0.443)	(0.569)	(0.562)
		0.081	0.077	0.056	0.052	-0.562	-4.461
		(0.470)	(0.458)	(0.567)	(0.579)	(0.519)	(0.708)

Table B.19: Estimation results for US indicators (4/4).

B.3 Standard Deviation of the Forecast Error

The forecast error of the analysts' forecasts is the difference between the expectations measured by a survey and the actual release. Table B.20 shows the standard deviation of the forecast error for German and Eurozone indicators and table B.21 for US indicators.

GER	sta.dev.	EUR	sta.dev.
Current Account	2.36	Current Account	3.45
Exports	2.67	Labour Cost Index	0.22
GDP, final, qoq	0.16	GDP, final, qoq	0.06
GDP, final, yoy	1.77	GDP, final, yoy	0.09
Industrial Orders, mom	2.25	Industrial Orders, mom	2.57
Industrial Orders, yoy	4.34	Industrial Orders, yoy	4.35
Industrial Production, mom	1.49	Industrial Production, mom	0.46
Industrial Production, yoy	1.20	Industrial Production, yoy	0.75
Retail Sales, mom	1.70	Retail Sales, mom	0.62
Retail Sales, yoy	2.20	Retail Sales, yoy	0.94
Trade Balance	1.85	Trade Balance	1.42
Unemployed	32.65	Unemployment Rate	0.08
Unemployment Rate	0.12	Consumer Prices, prel., yoy	0.08
Consumer Prices, final, mom	0.19	Consumer Prices, final, mom	0.09
Consumer Prices, final, yoy	0.12	Consumer Prices, final, yoy	0.06
Import Prices, mom	0.48	Producer Prices, mom	0.09
Import Prices, yoy	0.53	Producer Prices, yoy	0.13
Producer Prices, mom	0.25	Consumer Confidence	1.37
Producer Prices, yoy	0.25	Business Confidence	1.42
Ifo-Index	1.15	ESI	1.01
ZEW-Index	8.75		

Table B.20: Standard deviation of the difference between survey expectation and actual release for German and European indicators. The unit of the standard deviation is equal to the unit of the indicator.

US	sta.dev.	US	sta.dev.
Auto Sales	0.74	Trade Balance	2.46
Average Hourly Earnings	0.14	Unemployment Rate	0.13
Business Inventories	0.22	Unit Labour Costs, final	0.45
Capacity Utilisation	0.31	Consumer Price Index	0.12
Current Account	4.96	CPI Core	0.09
Durables Orders	2.95	PCE Core	0.09
GDP, final	0.44	Producer Price Index	0.43
Housing Permits	64.77	PPI Core	0.26
Housing Starts	93.87	Consumer Confidence	4.92
Industrial Production	0.28	Empire State Index	10.16
Industrial Orders	0.56	ISM Manufacturing	2.00
Initial Claims	18.04	ISM Non-Manufacturing	3.29
Non-Farm Payrolls	101.04	Leading Indicator	0.14
Personal Income	0.21	Philadelphia Fed	8.88
Personal Spending	0.19	PMI Chicago	4.09
Productivity, final	0.38	Help Wanted Index	1.52
Retail Sales	0.78	University of Michigan, final	2.08
Retail Sales Less Autos	0.47		

Table B.21: Standard deviation of the difference between survey expectation and actual release for US indicators. The unit of the standard deviation is equal to the unit of the indicator.

B.4 Figures of Significant Announcement Effects

B.4.1 Eurozone Indicators

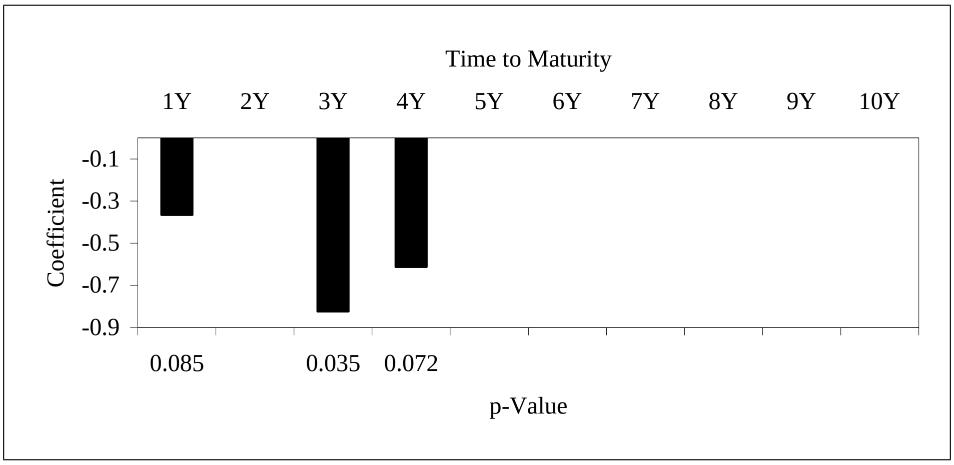

Figure B.1: Announcement effect of the Current Account in the Eurozone on interest rates of German government bonds with a maturity between one and ten years.

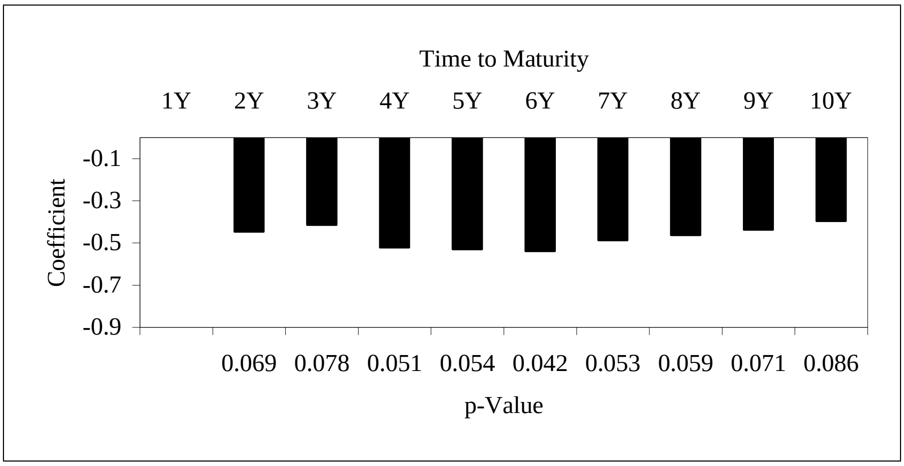

Figure B.2: Announcement effect of the Labour Cost index in the Eurozone on interest rates of German government bonds with a maturity between one and ten years.

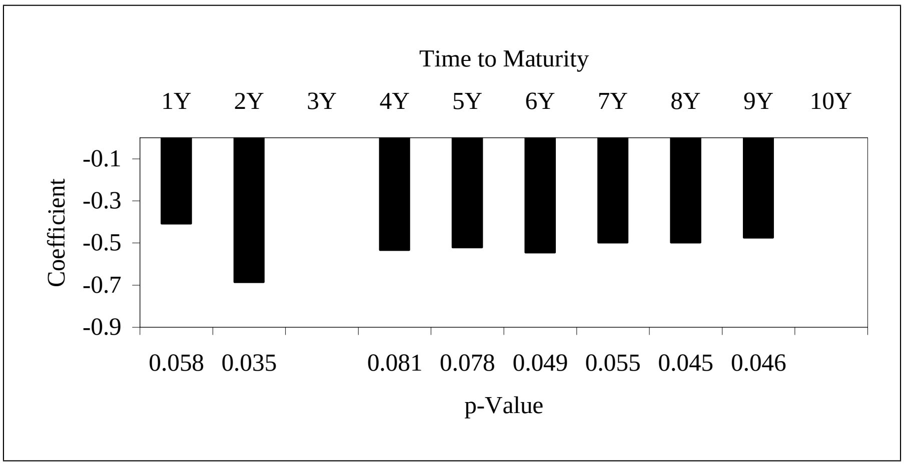

Figure B.3: Announcement effect of Industrial Orders (yoy) in the Eurozone on interest rates of German government bonds with a maturity between one and ten years.

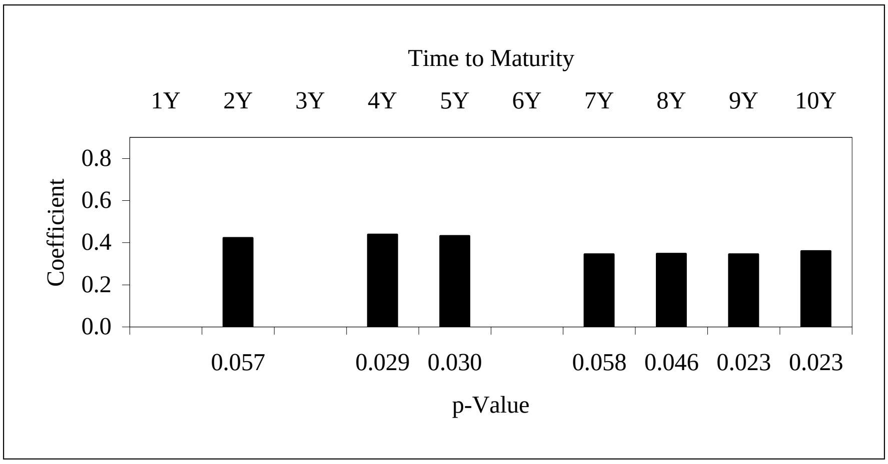

Figure B.4: Announcement effect of CPI (mom) in the Eurozone on interest rates of German government bonds with a maturity between one and ten years.

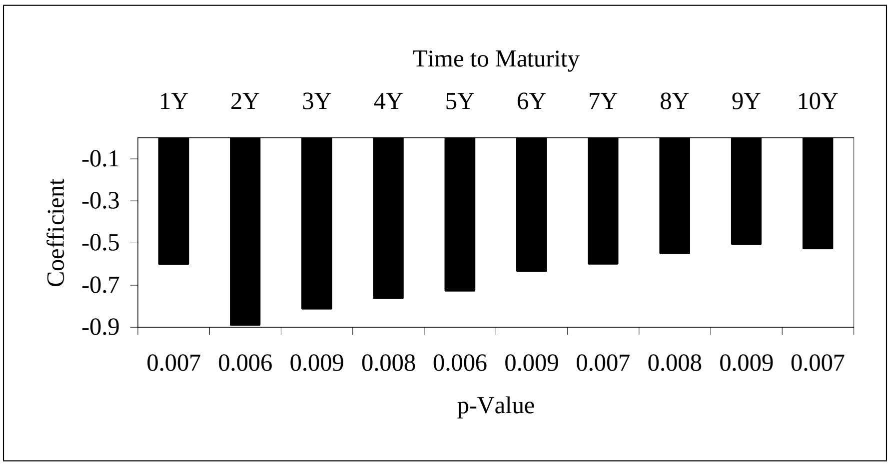

Figure B.5: Announcement effect of PPI (mom) in the Eurozone on interest rates of German government bonds with a maturity between one and ten years.

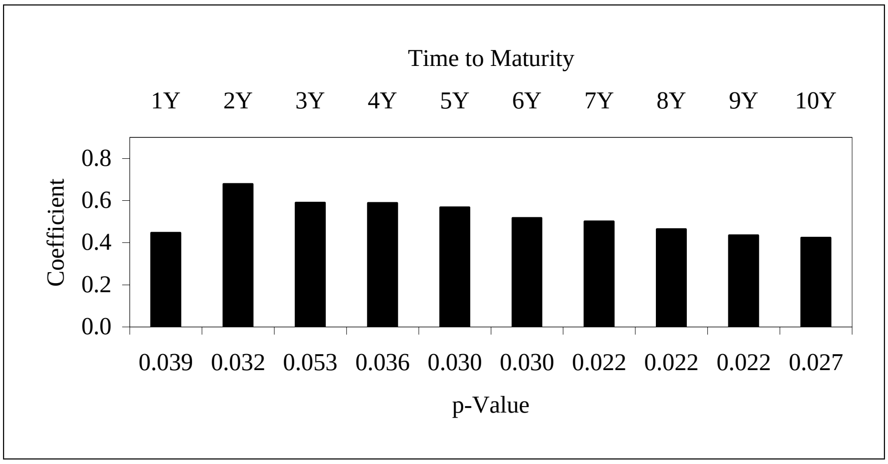

Figure B.6: Announcement effect of PPI (yoy) in the Eurozone on interest rates of German government bonds with a maturity between one and ten years.

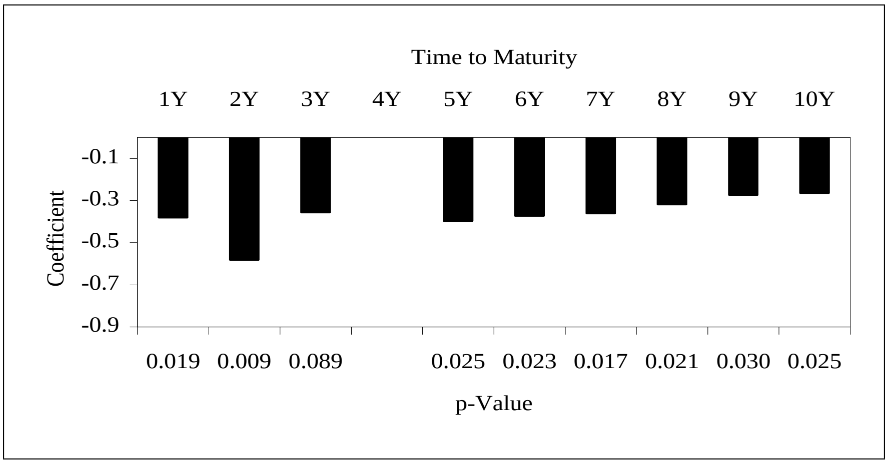

Figure B.7: Announcement effect of Business Confidence in the Eurozone on interest rates of German government bonds with a maturity between one and ten years.

B.4.2 US Indicators

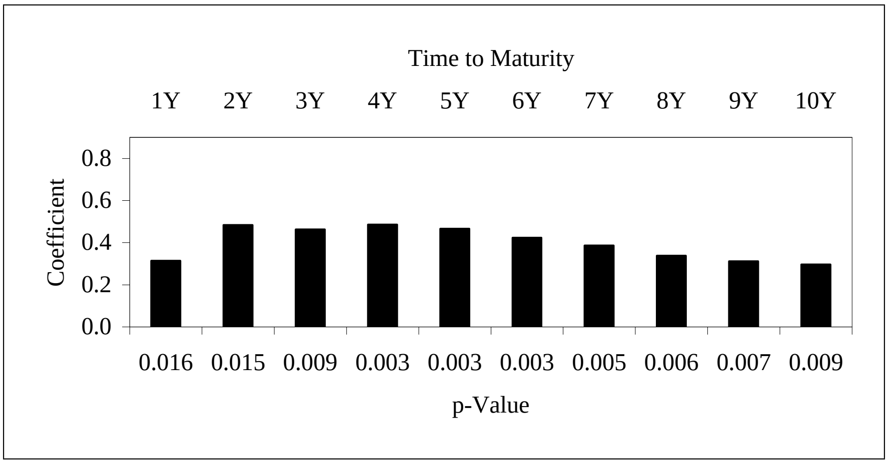

Figure B.8: Announcement effect of Average Hourly Earnings in the US on interest rates of German government bonds with a maturity between one and ten years.

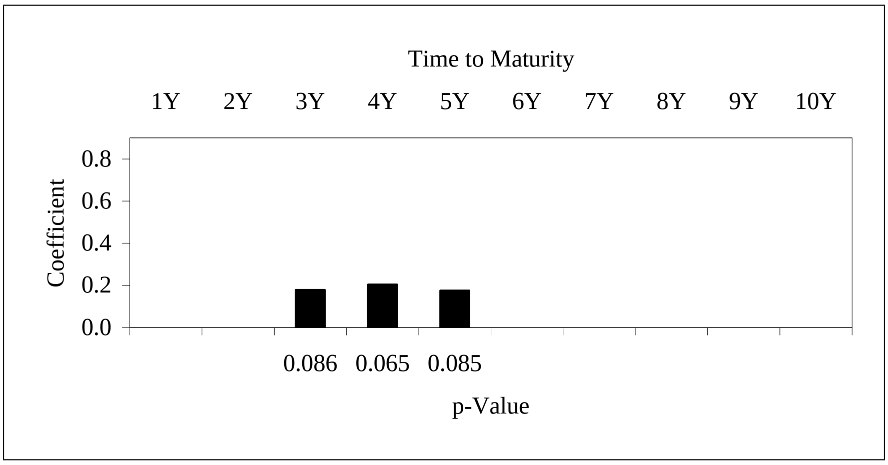

Figure B.9: Announcement effect of Durable Goods Orders in the US on interest rates of German government bonds with a maturity between one and ten years.

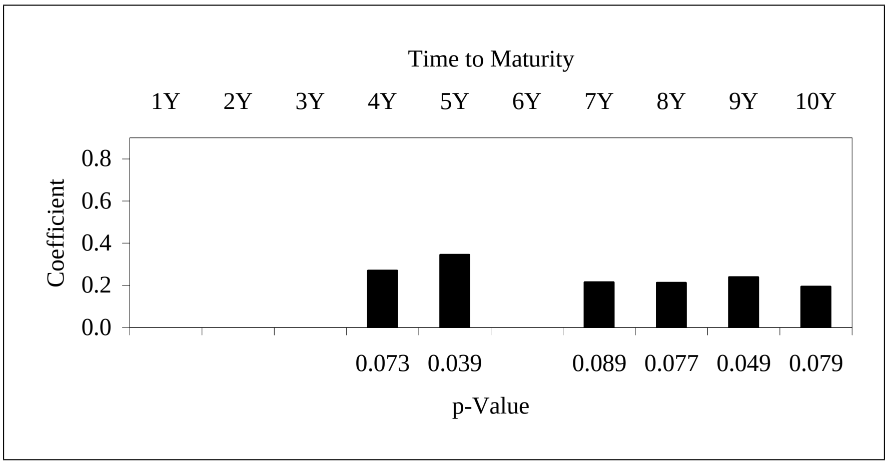

Figure B.10: Announcement effect of Industrial Production (mom) in the US on interest rates of German government bonds with a maturity between one and ten years.

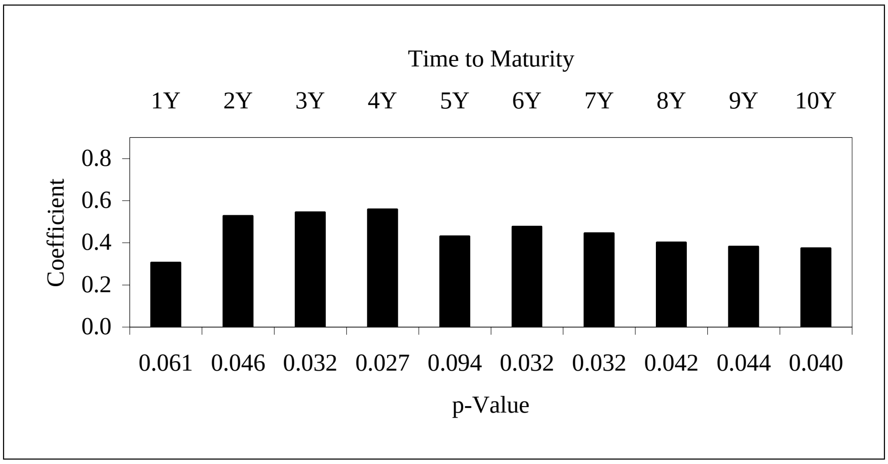

Figure B.11: Announcement effect of Retail Sales in the US on interest rates of German government bonds with a maturity between one and ten years.

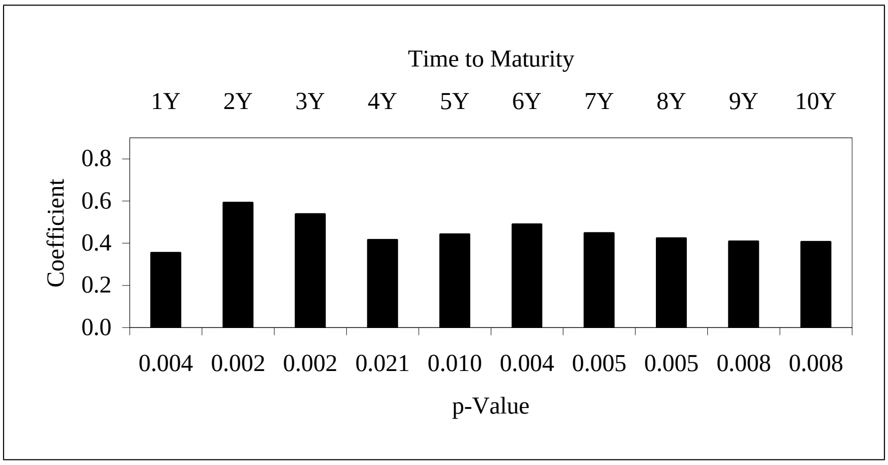

Figure B.12: Announcement effect of PCE Core in the US on interest rates of German government bonds with a maturity between one and ten years.

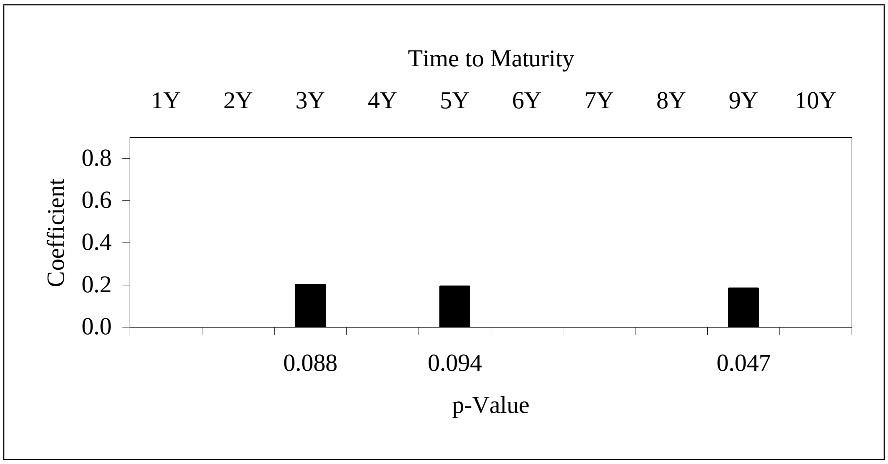

Figure B.13: Announcement effect of PPI Core in the US on interest rates of German government bonds with a maturity between one and ten years.

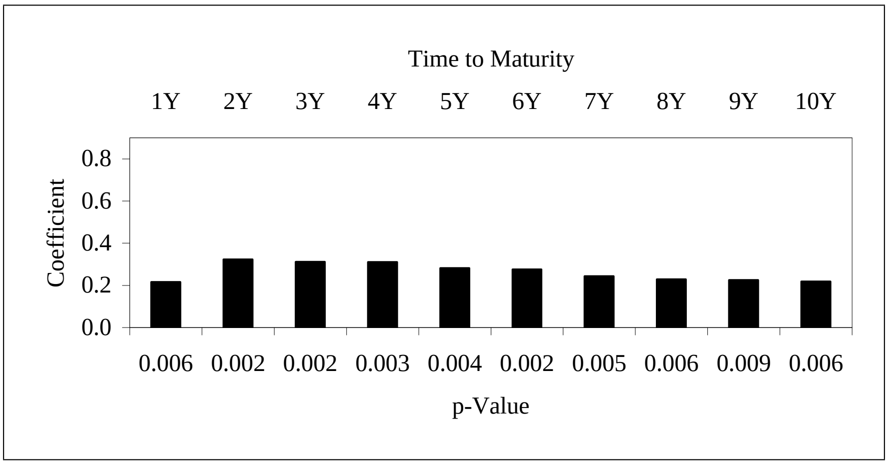

Figure B.14: Announcement effect of Consumer Confidence (Conference Board) in the US on interest rates of German government bonds with a maturity between one and ten years.

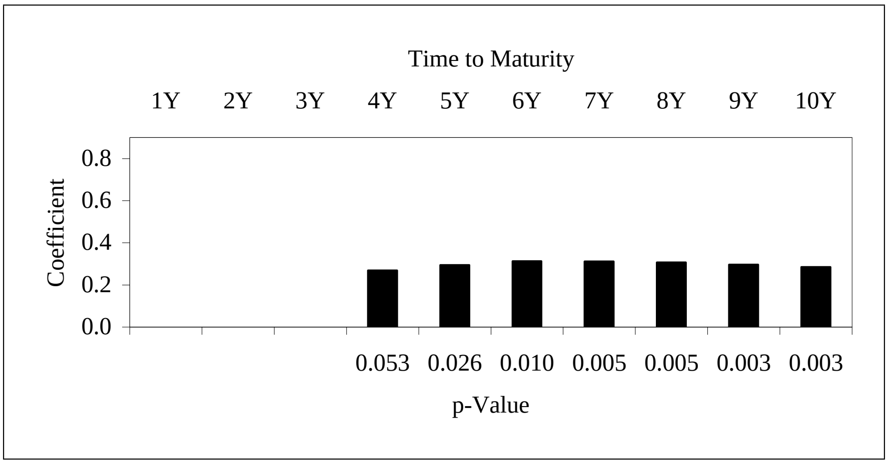

Figure B.15: Announcement effect of non-manufacturing ISM in the US on interest rates of German government bonds with a maturity between one and ten years.

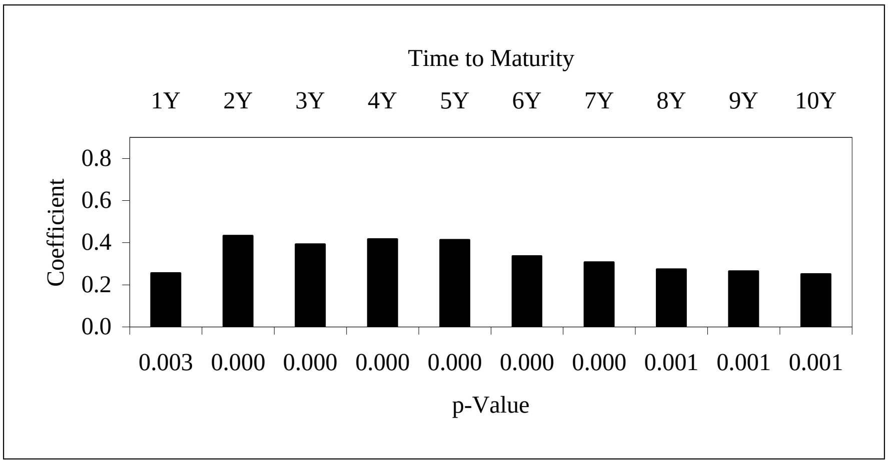

Figure B.16: Announcement effect of Chicago PMI in the US on interest rates of German government bonds with a maturity between one and ten years.

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08/2004	**London School of Economics**
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09/2004 - 12/2004	**Deutsche Bank Research, Frankfurt** Executive Assistant to Prof. Dr. Norbert Walter, Chief Economist Deutsche Bank Group (four-month limited position)
02/2004 - 04/2004	**Deutsche Bank Research, Frankfurt** Internship at team Macroeconomic Trends
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05/2001 - 07/2001	**Seminar for Macroeconomics, Munich** Student Assistant to Prof. Gerhard Illing

Miscellaneous

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